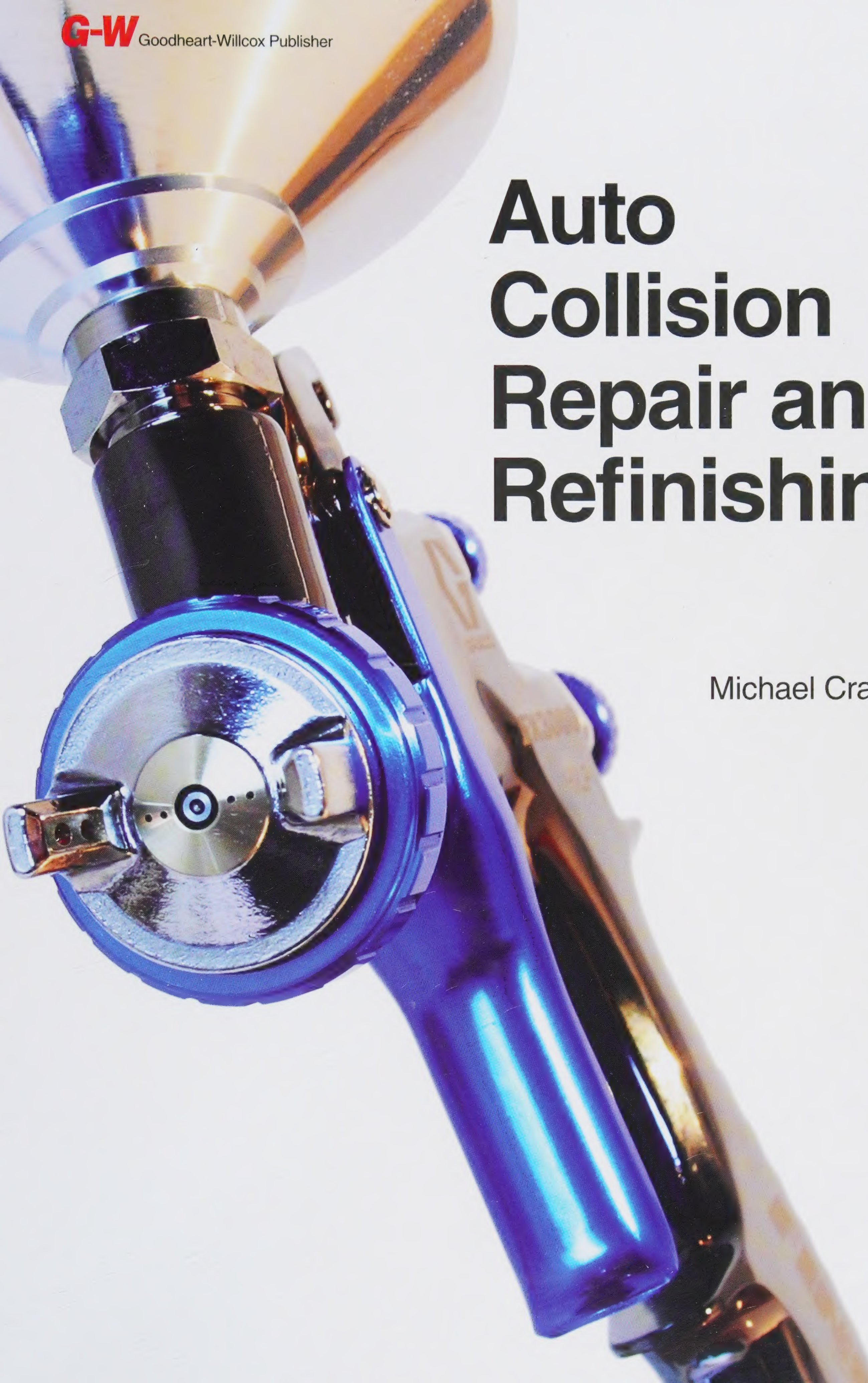
G-W Goodheart-Willcox Publisher

Auto Collision Repair and Refinishing

Michael Crandell



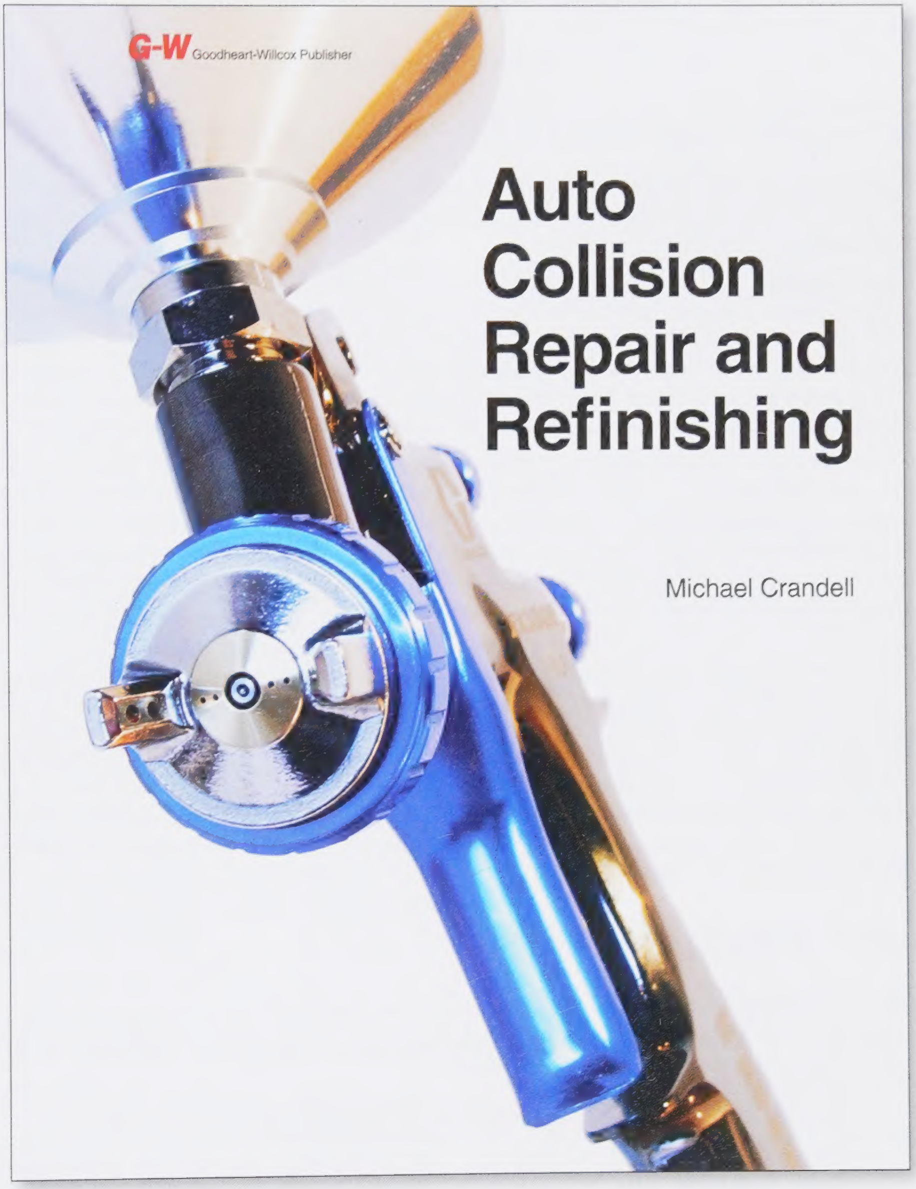
Digitized by the Internet Archive
in 2021 with funding from
Kahle/Austin Foundation

https://archive.org/details/autocollisionrep0000cran_g9u0

Auto Collision Repair and Refinishing

by

Michael Crandell


G-W Goodheart-Willcox Publisher
Auto Collision Repair and Refinishing
Michael Crandell

Publisher
The Goodheart-Willcox Company, Inc.
Tinley Park, IL
www.g-w.com

Copyright © 2014
by
The Goodheart-Willcox Company, Inc.

All rights reserved. No part of this work may be reproduced, stored, or
transmitted in any form or by any electronic or mechanical means, including
information storage and retrieval systems, without the prior written permission of
The Goodheart-Willcox Company, Inc.

Manufactured in the United States of America.

Library of Congress Catalog Card Number

ISBN 978-1-61960-387-5

2 3 4 5 6 7 8 9 – 14 – 18 17 16 15 14 13

The Goodheart-Willcox Company, Inc. Brand Disclaimer: Brand names, company names, and illustrations for products and services included in this text are provided for educational purposes only and do not represent or imply endorsement or recommendation by the author or the publisher.

The Goodheart-Willcox Company, Inc. Safety Notice: The reader is expressly advised to carefully read, understand, and apply all safety precautions and warnings described in this book or that might also be indicated in undertaking the activities and exercises described herein to minimize risk of personal injury or injury to others. Common sense and good judgment should also be exercised and applied to help avoid all potential hazards. The reader should always refer to the appropriate manufacturer's technical information, directions, and recommendations; then proceed with care to follow specific equipment operating instructions. The reader should understand these notices and cautions are not exhaustive.

The publisher makes no warranty or representation whatsoever, either expressed or implied, including but not limited to equipment, procedures, and applications described or referred to herein, their quality, performance, merchantability, or fitness for a particular purpose. The publisher assumes no responsibility for any changes, errors, or omissions in this book. The publisher specifically disclaims any liability whatsoever, including any direct, indirect, incidental, consequential, special, or exemplary damages resulting, in whole or in part, from the reader's use or reliance upon the information, instructions, procedures, warnings, cautions, applications, or other matter contained in this book. The publisher assumes no responsibility for the activities of the reader.

The Goodheart-Willcox Company, Inc. Internet Disclaimer: The Internet resources and listings in this Goodheart-Willcox Publisher product are provided solely as a convenience to you. These resources and listings were reviewed at the time of publication to provide you with accurate, safe, and appropriate information. Goodheart-Willcox Publisher has no control over the referenced websites and, due to the dynamic nature of the Internet, is not responsible or liable for the content, products, or performance of links to other websites or resources. Goodheart-Willcox Publisher makes no representation, either expressed or implied, regarding the content of these websites, and such references do not constitute an endorsement or recommendation of the information or content presented. It is your responsibility to take all protective measures to guard against inappropriate content, viruses, or other destructive elements.

Library of Congress Cataloging-in-Publication Data
Crandell, Michael
Auto Collision Repair and Refinishing/ by Michael Crandell —
1st ed.
p. cm.
Includes index.
ISBN 978-1-61960-387-5
1. Automobiles — Bodies — Maintenance and Repair.
I. Title

Introduction

The collision repair and refinishing industry has changed dramatically over the past several years. From laser-guided pulling systems to waterborne paints, many of today's tools, materials, and techniques are radically different from those commonly used just a decade ago. *Auto Collision Repair and Refinishing* provides instruction on the latest collision repair and refinishing techniques, as well as more traditional repair procedures. This book presents both the theoretical and practical aspects of collision repair and refinishing in an easy-to-understand manner. It will help you prepare for a fast-paced workplace that is becoming increasingly technical.

Organized around the NATEF Collision Repair and Refinishing Task List, *Auto Collision Repair and Refinishing* contains 35 detailed chapters grouped into six sections. This comprehensive textbook includes information on structural repair, nonstructural repair, refinishing, and detailing. Chapters on mechanical systems, such as brake systems, cooling systems, and restraint systems, allow students to recognize and repair common types of mechanical damage encountered during the collision repair process. An extensive estimating chapter provides unsurpassed instruction on this vital task, walking students through the steps required to estimate specific types of damage.

Chapter Components

Each chapter of *Auto Collision Repair and Refinishing* opens with a list of learning objectives. These objectives identify the critical skills you will need to master to succeed in this profession. Review the objectives before reading the chapter to get an understanding of the material to come. After completing the chapter, review the objectives once more as a review of chapter material.

Important technical terms used in the profession are also listed at the beginning of each chapter and appear in bold italic type when introduced in the chapter. After completing a chapter, review and define each term. If a technical term cannot be defined at that time, go back and review the related section in the chapter.

A chapter summary is included at the end of each chapter. The summary provides a brief overview of the material covered in the chapter. Review the summary after reading a chapter. If something in a summary is not understood, go back and review the related section in the chapter.

Two types of review questions are presented at the end of each chapter: conventional review questions and ASE-type questions. The conventional review questions help you solidify your understanding of important concepts. This information establishes the foundation on which a thorough knowledge of collision repair and refinishing procedures is based. The ASE-type questions are designed to help you prepare for the types of questions you will encounter on the ASE Collision Repair and Refinishing certification tests. After completing a chapter, answer all the end-of-chapter questions on a separate sheet of paper. This is a great way to review the material just presented in the chapter.

Type Fonts Used in This Text

Throughout the chapters of this text, different type fonts are used to emphasize the meaning or use of words, to identify important terms, and to identify figure references.

Words or terms that are called out and emphasized always appear in *italic* type. Important technical terms appear in ***bold-italic*** type. These important terms can be found in the *Technical Terms* list at the beginning of the chapter in which they appear, and are listed in the glossary at the back of this text.

Figure references in the body of the text and those found with the illustrations always appear in **bold** type. This makes it easy to identify the reference in body text and the corresponding illustration on the page.

Special Notices and Features

There are a variety of notices and features used throughout this text to emphasize safe work practices and provide supplemental information related to the system or procedure being discussed. They are identified by color, an icon, and a colored border. The notices and features are as follows:

CAUTION

A caution identifies hazards that may result in temporary or permanent damage of equipment or tools if the proper procedures or safety measures are not followed. If a caution is not understood, always consult a supervisor or instructor.

WARNING

A warning identifies hazards that may result in personal injury if the proper procedures or safety measures are not followed. If a warning is not understood, always consult a supervisor or instructor.

NOTE

A note is used to highlight technical information that is critical to the collision repair and refinishing process.

WORKING SMART

Working Smart features contain tips for performing collision repair and refinishing procedures more efficiently.

WORKING GREEN

Working Green features call attention to collision repair and refinishing operations that impact the environment and provide tips for lessening this impact.

Supplementing the Textbook

A comprehensive workbook is available for use with the *Auto Collision Repair and Refinishing* textbook. The workbook contains learning objectives and a variety of questions organized to correlate with the chapters in this text and provide a means to demonstrate your understanding of the equipment, materials, skills, and techniques encountered in the collision repair and refinishing profession. The workbook also contains several jobs that walk you through important collision repair and refinishing operations step by step. These jobs give you the opportunity to develop the hands-on skills needed to succeed in the collision repair shop.

Auto Collision Repair and Refinishing is an indispensible resource for students preparing for a career in collision repair and refinishing, as well as experienced technicians preparing for the ASE Collision Repair and Refinishing certification tests. Reading and understanding the material in this book will help you prepare for a job in any area of collision repair.

Brief Contents

Section 1 Introduction to Collision Repair

Chapter 1 Introduction to Collision Repair 17
Chapter 2 Safety 31
Chapter 3 Vehicle Construction 53
Chapter 4 Fundamentals of Collision Damage 69
Chapter 5 Welding and Cutting 89
Chapter 6 General Purpose Tools and Equipment, Service Information 117

Section 2 Nonstructural Repairs

Chapter 7 Nonstructural Repair Tools, Equipment, and Materials 137
Chapter 8 Nonstructural Panel Repair 165
Chapter 9 Bolted Nonstructural Part Replacement 197
Chapter 10 Welded and Bonded Nonstructural Panel Replacement 225
Chapter 11 Plastic Repair 255
Chapter 12 Glass 281

Section 3 Structural Repairs

Chapter 13 Unibody/Frame Straightening Equipment 303
Chapter 14 Measurements 327
Chapter 15 Unibody Straightening 353
Chapter 16 Full-Frame Repair 379
Chapter 17 Structural Component Replacement 409

Section 4 Mechanical and Electrical Repairs

Chapter 18 Steering and Suspension 437
Chapter 19 Electrical System 475
Chapter 20 Brakes 497
Chapter 21 Cooling, Heating, and Air Conditioning Systems 513
Chapter 22 Power Train 531
Chapter 23 Restraint Systems 553

Section 5 Refinishing

Chapter 24 Refinishing Tools and Equipment 573
Chapter 25 Refinish Materials 603
Chapter 26 Paint Mixing and Reducing 631
Chapter 27 Spray Technique 649
Chapter 28 Surface Preparation 671
Chapter 29 Color Matching 701
Chapter 30 Paint Application 719
Chapter 31 Specialty Painting 745
Chapter 32 Detailing 761

Section 6 Estimating and Certification

Chapter 33 Estimating 785
Chapter 34 ASE Certification 819
Chapter 35 Employment Strategies 829

Appendix 837
Acknowledgments 845
Glossary 846
Index 868

Expanded Contents

Section 1

Introduction to Collision Repair

Chapter 1

Introduction to Collision Repair 17
Introduction 18
The Repair Process 18
Insurance Claims 18
Ordering Parts 19
Body Repairs 21
Mechanical Repairs 22
Refinishing 23
Reassembly 24
Detailing 24
Body Shop Types 24
Collision Repair Industry Jobs 25
Body Shop Employees 25
Body Repair Support Positions 26
Educational Opportunities 27
ASE 28
I-CAR 28

Chapter 2

Safety 31
Introduction 32
Collision Repair Shop Hazards 32
Fire Hazards 32
Explosion Hazards 33
Chemical and Biological Hazards 35
Electrical Hazards 36
Noise Hazards 36
Injury Hazards 37
Personal Protective Gear 39
Eye Protection 39
Ear Protection 40
Respiratory Protection 40
Skin Protection 42
Safe Work Practices 42
Welding and Cutting Safety 43
Straightening Equipment Safety 44
Grinding and Cutting Safety 45
Sanding Safety 46
Painting Safety 46
Mechanical Repair Safety 47
Hazardous Wastes 48
Environmental Regulations 49
Environmental Protection Agency 49
Occupational Safety and Health Administration 50

Chapter 3

Vehicle Construction 53
Introduction 54
Vehicle Classifications 54
Vehicle Construction 54
Drive Train Orientation 55
Body Styles 55
Material Types 57
Steel 58
Aluminum 59
Magnesium 60
Plastic 60
Glass 60
Vehicle Parts 60
Outer Body Assemblies 61
Inner Body Assemblies 63
Vehicle Production 65
Vehicle Safety Rating 66

Chapter 4

Fundamentals of Collision Damage 69

- **Introduction ... 70**
- **Vehicle Design Factors ... 70**
  - Metal Properties ... 70
  - Component Shapes ... 71
- **Collision Factors ... 72**
  - Force ... 72
  - Inertia ... 75
  - Target ... 76
  - Impact Angle ... 76
  - Surface Area of Impact ... 76
  - Vehicle Height ... 77
- **Damage ... 77**
  - Direct and Indirect Damage ... 78
  - Bend-versus-Kink Rule ... 79
  - Full-Frame Damage ... 79
  - Unibody Damage ... 83

Chapter 5

Welding and Cutting ... 89

- **Introduction ... 90**
- **Welding Safety ... 90**
- **Welding Fundamentals ... 92**
  - Weld Types ... 92
  - Welding Position ... 92
  - Joint Types ... 93
  - Fit Up ... 93
  - Preparation for Welding ... 93
- **MIG Welding ... 93**
  - Weld Terminology ... 96
  - MIG Welding Variables ... 96
  - MIG Welding Machine Setup ... 98
  - Testing Welds ... 102
  - MIG Welding Aluminum ... 104
- **Flux-Cored Arc Welding ... 105**
- **Tungsten Inert Gas Welding ... 106**
- **Resistance Welding ... 107**
  - Squeeze-Type Resistance Spot Welding Machines ... 107
  - Panel Spotter ... 109
- **Using an Oxyacetylene Torch ... 109**
  - Lighting an Oxyacetylene Torch ... 110
- **Heating Steel Parts ... 110**
- **Brazing ... 111**
- **Cutting Steel Parts ... 111**
  - Using a Plasma Cutter ... 111
  - Using an Oxyacetylene Cutting Torch ... 112

Chapter 6

General Purpose Tools and Equipment, Service Information ... 117

- **Introduction ... 118**
- **Tool Storage ... 118**
- **General-Purpose Hand Tools ... 119**
  - Wrenches ... 119
  - Pliers ... 121
  - Screwdrivers ... 122
  - Pry Bars ... 122
  - Hammers ... 123
  - Chisels and Punches ... 123
  - Tap and Die Set ... 124
  - Hacksaw ... 125
  - Snips ... 125
  - Rivet gun ... 125
  - Scrapers ... 126
  - Utility Knives ... 126
  - Upholstery Removal Tools ... 126
- **Power Tools ... 127**
  - Impact Wrench ... 127
  - Air Ratchet ... 127
  - Drills and Drill Bits ... 127
- **Shop Equipment ... 128**
  - Compressed Air System ... 128
  - Floor Jack ... 128
  - Jack Stands ... 129
  - Lifts ... 129
  - Creepers and Shop Seats ... 131
  - Service Cart ... 131
  - Welding Equipment ... 131
- **Service Information ... 132**

Section 2
Nonstructural Repairs

Chapter 7

Nonstructural Repair Tools, Equipment, and Materials ... 137

- **Introduction ... 138**
- **Body Repair Hand Tools ... 138**
  - Body Hammers ... 138
  - Dollies ... 141
  - Spoons ... 142
  - Picks ... 142
  - Slide Hammer ... 143
  - Friction Jack ... 143

- Alignment Bar ... 144
- Door Removal and Alignment Tools ... 144
- Body Chisel ... 145
- Metal Files ... 145
- Bull's-Eye Pick ... 146
- Panel Flanger ... 146
- Hand Punch ... 146
- Filler Tools ... 146
- Shaping and Sanding Tools ... 147
- Cable-Tensioning Devices ... 150

Panel Repair Power Tools ... 151
- Grinder ... 151
- Air File ... 152
- Orbital Sander ... 152
- Spot Weld Cutters ... 153
- Air Punch/Flanger ... 153
- Cut-Off Tool ... 154
- Air Chisel ... 154
- Air Saw ... 154
- Electric Shears ... 155
- Door Skin Replacement Tool ... 155
- Draw Pin Welder ... 156
- Rod Welder ... 157
- Weld-on Plate ... 157
- Hydraulic Power Set ... 158

Nonstructural Repair Materials ... 158
- Body Fillers ... 158
- Sandpaper ... 159
- Adhesives ... 161

Chapter 8

Nonstructural Panel Repair ... 165

Introduction ... 166

Fundamentals of Damage Repair ... 166

Nonstructural Panel Repair Steps ... 166
- Reading the Estimate ... 167
- Analyzing Damage ... 167
- Planning the Repair ... 168
- Accessing Damage ... 169
- Roughing Out ... 171
- Roughing Out Specific Types of Damage ... 181
- Arrowheads ... 184
- Finishing ... 187

Aluminum Panel Repair Operations ... 194

Chapter 9

Bolted Nonstructural Part Replacement ... 197

Introduction ... 198

Part Sources ... 198
- OEM Parts ... 198
- Used Parts ... 198
- Aftermarket Parts ... 199

Bolted Part Replacement Steps ... 199
- Read the Estimate ... 199
- Analyze the Damage ... 199
- Plan the Repair ... 200
- Remove the Damaged Parts ... 200
- Fit Up ... 200
- Final Assembly ... 201

Replacing Specific Bolted Parts ... 201
- Steel Bumpers ... 202
- Plastic Bumpers ... 204
- Header Panel ... 206
- Fenders ... 207
- Hood ... 210
- Doors ... 214
- Deck Lid ... 218
- Rear Hatch ... 219
- Sliding Door ... 220
- Pickup Bed ... 221

Chapter 10

Welded and Bonded Nonstructural Panel Replacement ... 225

Introduction ... 226

Welded and Bonded Nonstructural Panel Replacement Steps ... 226
- Reading the Estimate ... 226
- Analyzing the Damage ... 226
- Planning the Repair ... 227
- Accessing the Damage ... 228
- Rough Cutting ... 228
- Final Cutting ... 231
- Preparing Panels ... 231
- Fit Up ... 233
- Joining ... 234
- Finishing ... 236

Replacing Specific Nonstructural Panels ... 237
- Quarter Panel Replacement ... 237
- Roof Replacement ... 240
- Rear Body Panel Replacement ... 244
- Bed Side Replacement ... 244
- Cab Corner Replacement ... 246
- Van Side Replacement ... 247
- Door Skin Replacement ... 247
- Patch Panel Installation ... 251

Chapter 11

Plastic Repair ... 255

Introduction ... 256

Classifying Plastics ... 257

Tools and Materials ... 257
- Die Grinder ... 257
- Plastic Welder ... 257
- Adhesives ... 260

Adhesion Promoter 261
Mesh 261
Fiberglass 261
Plastic Repair Steps **262**
Read the Estimate 262
Remove the Damaged Part 262
Clean the Repair Area 263
Identify the Plastic to be Repaired 263
Plan the Repair 263
Align the Damaged Parts 264
Make the Repair 265
Finishing 269
Repairing Specific Types of Damage **270**
Flexible or Semi-Rigid Non-Olefin Plastic Gouge (RIM, RRIM, Xenoy, GTX, Pulse, Urethane) ... 271
Flexible or Semi-Rigid Tear—Binding Repair (Urethane, RIM, RRIM, Xenoy, GTX, Pulse, TPO, TEO, PP) ... 271
Flexible or Semi-Rigid Non-Olefin Plastic Tear—Adhesive Repair (RIM, RRIM, Xenoy, GTX, Pulse, Urethane) ... 272
Olefin Gouge (TPO, TEO) 273
Olefin Tear—Bonding Repair (TPO, TEO) 273
Thermoplastic Break (Xenoy, ABS, TPO, TEO, PP, PE) ... 274
SMC or FRP Scratch 275
SMC Break 275
SMC Splice 276
FRP Break 276

Chapter 12

Glass **281**
Introduction **282**
Types of Glass **282**
Movable and Fixed Glass **283**
Movable Glass 283
Fixed Glass 285
Glass Removal and Installation Tools **288**
Glass Repair Materials 291
Glass Service **292**
Rolling Glass 292
Sliding Glass 293
Hinged Glass 293
Turning Glass 294
Bolted Fixed Glass 294
Rubber-Set Glass, No Locking Strip 294
Rubber-Set Glass, Locking Strip 295
Urethane-Set Glass 295
Encapsulated Glass 298
Leak Checks 298

Section 3

Structural Repairs

Chapter 13

Unibody/Frame Straightening Equipment **303**
Introduction **304**
Pulling Equipment **304**
Pulling Chain 304
Chain Hooks 305
Tie-Downs 306
Hookups 309
Hydraulic Rams 313
Pulls **315**
Tower Pull 315
Vector Pull 316
Swing Arm Pull 317
Frame Machine Types **318**
Portable Systems 318
Floor Pot System 318
Frame Bench 320
Frame Rack 321
Bench/Rack 322
Floor Rail System 322

Chapter 14

Measurements **327**
Introduction **328**
Linear Measurements **328**
One-Dimensional Measurements **331**
Measuring Tools for One-Dimensional Measurements ... 334
Two-Dimensional Measurements **336**
Measuring Tools for Two-Dimensional Measurements ... 336
Three-Dimensional Measurements **340**
Measuring Tools for Three-Dimensional Measurements ... 341
Damage Diagram **349**

Chapter 15

Unibody Straightening 353
- Introduction 354
- Basic Unibody Straightening Operations 354
  - Tear Down 354
  - Identify Damage 354
  - Plan 355
  - Tie-Downs 356
  - Hookups 357
  - Straightening Damage 359
  - Stress Relief 363
- Straightening Specific Types of Unibody Damage 365
  - Unirail Flange Bent 365
  - Front Unirail Sag 366
  - Front Unirail Kickup 366
  - Front Unirail Sidesway 367
  - Unirail Mash 367
  - A-Pillar Pushed Rearward 368
  - A-Pillar Pushed Inward 368
  - Roof Rail Up 370
  - Twist 371
  - Center Pillar In 371
  - Rocker Panel In 373
  - Roof Down 374
  - Rear Unirail Damage 375
- Access Windows 376

Chapter 16

Full-Frame Repair 379
- Introduction 380
- Basic Frame Straightening Operations 380
  - Damage Analysis 381
  - Part Removal 381
  - Tie-Downs 382
  - Hookups 386
  - Pulls 390
  - Pushes 393
  - Stress Relief 393
- Repairing Specific Types of Frame Damage 394
  - Repairing Buckles 395
  - Repairing a Rolled Rail 398
  - Repairing a Collapsed Cross Member 398
  - Repairing Widening 399
  - Repairing Sidesway 399
  - Repairing Sag 401
  - Repairing Kickup 401
  - Repairing Twist 402
  - Repairing Diamond Damage 402
  - Repairing Mash 403
  - Repairing Combination Damage 404

Chapter 17

Structural Component Replacement 409
- Introduction 410
- Structural Panel Replacement Procedures 410
  - Disassemble 410
  - Straighten 410
  - Plan 411
  - Remove the Damaged Panel 412
  - Pretreat 413
  - Fit Up 414
  - Join 415
  - Rustproof and Paint 418
  - Replace Foam 418
  - Reassemble 419
- Replacement Part Sources 419
  - Front Section 420
  - Side Section 420
  - Rear Section 420
  - Rear Section and Roof 420
- Replacing Structural Unibody Components 421
  - Radiator Support 421
  - Apron 423
  - Shock Tower 423
  - Upper Frame Rail 424
  - Lower Front Frame Rail 425
  - A-pillar 425
  - Rocker Panel 427
  - Center Pillar 428
  - Rear Frame Rail and Trunk Floor 430
  - Clipping 431
- Replacing Full-Frame Components 432
  - Full-Frame Sectioning 432
  - Full-frame Replacement 433

Section 4

Mechanical and Electrical Repairs

Chapter 18

Steering and Suspension 437
- Introduction 438

Steering System 438
- Steering System Parts 438

Steering System Types 439
- Rack-and-Pinion Steering 439
- Parallelogram Steering 440
- Power Steering Systems 440

Suspension Systems 441
- Suspension System Components 441
- Front Suspension Types 443
- Rear Suspension Types 445
- Electronic Suspension Systems 445

Hub and Wheel Assemblies 447
- Wheel Hubs and Bearings 447
- Wheels 447
- Tires 448
- Tire Pressure Monitoring Systems 449

Diagnosing Steering, Suspension, and Wheel Assembly Damage 449
- Inspection 450

Steering and Suspension System Repair 454
- Replacing an Outer Tie Rod (Tie Rod End) 454
- Replacing an Inner Tie Rod 455
- Replacing a Center Link 455
- Replacing a Rack-and-Pinion Gearbox 456
- Replacing a Parallelogram Steering Gearbox 456
- Replacing a MacPherson Strut 456
- Replacing a Modified MacPherson Strut 457
- Replacing a Coil Spring—Short Long Arm Suspension 457
- Replacing a Coil Spring—Solid Rear Axle 457
- Replacing a Control Arm 458
- Replacing a Steering Knuckle 458
- Replacing a Leaf Spring 458
- Replacing a Stabilizer Bar and Links 459
- Removing and Installing a Steering Column 459

Wheel and Tire Service 460
- Servicing Tapered Roller Bearing Wheel Bearings 460
- Removing and Installing Sealed Wheel Bearings 460
- Removing and Installing a Tire 461
- Balancing a Tire and Wheel 462

Alignment 462
- Wheel Alignment Angles 464
- Alignment Procedures 465
- Installing Control Heads 466
- Measuring Actual Alignment Values 467
- Adjusting Alignment Angles 468

Chapter 19

Electrical System 475

Introduction 476

Basic Electricity 476
- Units of Electricity 476
- Ohm's Law 476
- Electrical Components and Circuits 477
- Circuit Problems 478

Basic Electrical Parts 478
- Wire 478
- Wire Terminals and Connectors 478
- Switches and Relays 479
- Fuses, Fusible Links, and Circuit Breakers 480
- Motors 480

Basic Electrical Systems 481
- Battery, Charging System, and Starting System 481
- Lighting System 482
- Horn System 483
- Windshield Wiper and Washer Systems 484
- Power Accessory Systems 484

Basic Electrical Tests and Service Operations 486
- Using a Test Light 487
- Using a Jumper Wire 488
- Digital Multimeter 488
- Using Wiring Diagrams 489
- Wiring Repairs 489

Electrical System Service 490
- Battery and Alternator Service 490
- Lighting System Service 491
- Aiming Headlights 492
- Horn Service 494
- Windshield Wiper and Washer Service 494
- Power Accessory Service 494

Chapter 20

Brakes 497

Introduction 498

Brake System Operation 498

Brake System Parts 499
- Brake Fluid 499
- Master Cylinder 500
- Brake Lines and Hoses 500
- Drum Brakes 501
- Disc Brakes 502
- Valves 502
- Anti-Lock Brake System 503
- Traction Control and Electronic Stability Systems 504

Brake System Repair 505
- Servicing Worn Components 505
- Disconnecting a Brake Line or Hose 506
- Moving a Brake Line 506
- Replacing a Brake Line 506
- Replacing a Brake Hose 507
- Brake Bleeding 507
- Servicing Drum Brakes 508
- Servicing Disc Brakes 509
- Inspecting ABS Components 509

Chapter 21

Cooling, Heating, and Air Conditioning Systems 513

Introduction 514

Cooling System 514
- Cooling System Parts 514
- Cooling System Damage 517
- Cooling System Service 518

Heating System 521
- Heating System Parts 521
- Heating System Damage 521

Air Conditioning System 521
- Air Conditioning System Parts 522
- Air Conditioning System Damage 524
- Air Conditioning System Service 525
- Condenser Service 525
- Air Conditioning System Recovery, Evacuation, and Recharging 527
- Check for Air Conditioning System Leaks 528

Chapter 22

Power Train 531

Introduction 532

Engine Components 532
- Air Intake System 533
- Fuel System 533
- Emissions Control System 534
- Engine Pulleys 534
- Motor Mounts 535
- Exhaust System 535

Drivetrain Components 536
- Rear-Wheel-Drive Components 536
- Front-Wheel-Drive Components 539
- Four-Wheel-Drive and All-Wheel-Drive Components 540

Power Train Service and Repair 541
- Checking Fluids 541
- Fuel and Emission Control System Service 542
- Exhaust System Service 543
- Drive Belt and Pulley Service 543
- Adjusting Linkages 544
- Removing and Installing a Motor Mount 544
- Removing and Installing a Front-Wheel-Drive Engine and Transaxle Assembly 544
- Removing and Installing a Rear-Wheel-Drive Power Train (Longitudinal Engine) 547
- Four-Wheel-Drive and All-Wheel-Drive Component Service 549

Chapter 23

Restraint Systems 553

Introduction 554

Restraint System Types 554

Interior Components 554
- Seats 554
- Dashboard 555
- Steering Column 555
- Windshield 555
- Seat Belts 555
- Air Bags 557
- Advanced Air Bag System 560

Restraint System Service 562

Section 5

Refinishing

Chapter 24

Refinishing Tools and Equipment 573

Introduction 574

Hand Tools 574
- Sanding Tools 574
- Removal Tools 576
- Application Tools 576

Power Tools 577
- Sanding Tools 577
- Blow Gun 578
- Buffers 578
- Removal Tools 578
- Heat Gun 578
- Spray Guns 578

Refinishing Equipment 583
- Spray Booths 583
- Prep Station 587
- Paint Mixing Room 587
- Drying Equipment 587
- Air Drying 589
- Spray Gun Cleaner 589
- Vacuum System 590
- Solvent Recycler 590
- Compressed Air System 590
- Recycling Air System 597

Additional Refinishing Equipment 598
- Masking Equipment 598
- Pressure Washer 598
- Painting Platform 598
- Panel Positioners 598
- Blasting Equipment 598
- Siphon Blaster 599
- Captive Blaster 599
- Pressure Blaster 599
- Vacuum Blaster 599
- Cabinet Blaster 599
- Infrared Thermometer 600

Chapter 25

Refinish Materials 603

Introduction 604

Types of Paint 604

Paint Components 605
- Binder 605
- Pigment 606
- Solvent 606
- Additives 606
- Paint Diluting Elements 606

Topcoats 609
- Single-Stage Paints 610
- Basecoat/Clearcoat Paints 611
- Tri-Coat Paints 612

Specialty Topcoats 612
- Powder Coating 612
- Spray-On Bed Liner 613

Undercoats 613
- Etchers 613
- Primers 614
- Surfacer 615
- Sealer 616
- Dual-Use Undercoats 617
- Rock Guard 617
- Adhesion Promoter 618

Abrasives 618
- Sandpaper 618
- Blasting Material 621
- Cut-Off Wheel 621
- Grinding Disk 621
- Abrasive Disks 622
- Abrasive Pads 622
- Sanding Paste 623

Chemical Paint Removal 623
- Paint Stripper 623
- Cleaners 623
- Masking Materials 625
- Mixing and Straining Supplies 627
- Buffing Materials 628

Chapter 26

Paint Mixing and Reducing 631

Introduction 632

Paint Mixing 632
- Paint Code 632
- Paint Part Number 632
- Paint Sources 634
- Paint Mixing Equipment 634
- Paint Mixing Supplies 636
- Paint Formula 637
- Color Creation 638

Paint Reduction 639
- Stirring 639
- Reducer Type 640
- Hardener Type 640
- Viscosity 640
- Volume Reduction 641
- Weight Reduction 644

Chapter 27

Spray Technique 649

Introduction 650
- Paint Characteristics 650
- Adjustments 650
- Spray Gun Setup 651
- Setting Up a Conventional Spray Gun 651
- Setting Up an HVLP Spray Gun 652
- Balancing the Spray Gun 654
- Pattern Test 654
- Flood Test 655

Basic Painting Skills 656

Spray Gun Handling 656
- Body Position 657
- Fan Orientation 657
- Distance 658
- Travel Speed 659
- Overlap 660
- Stroke 660
- Triggering 661

Match the Technique to the Job 661
- Medium Wet Coat 661
- Full Wet Coat 661
- Drop Coat 662
- Mist Coat 662
- Tack Coat 662

    - Blend coat ... 662
    - Paint Type ... 662
- **Spraying Body Panels ... 662**
    - Painting Long Panels ... 662
    - Panel Refinishing ... 663
- **Other Painting Considerations ... 665**
    - Spray Booth Type ... 665
    - Air Hose ... 666
- **Spray Gun Cleaning ... 667**

Chapter 28

Surface Preparation ... 671

- **Introduction ... 672**
- **Surface Preparation Standards ... 672**
- **Basic Surface Preparation Procedures ... 673**
    - Inspect ... 673
    - Plan ... 675
    - Wash ... 676
    - Remove Obstructions ... 676
    - Pre-Sand Cleaning ... 676
    - Paint Removal ... 677
    - Masking for Undercoats ... 680
    - Metal Conditioning ... 682
    - Apply Undercoats ... 682
    - Block Sanding ... 684
    - Finish Sand ... 686
    - Blow off Vehicle ... 687
    - Clean with Pre-Paint Solvent ... 687
    - Mask for Topcoat ... 687
    - Blow off Vehicle ... 692
    - Tack ... 692
    - Seam Sealer ... 692
    - Rocker Panel Spray ... 694
    - Aluminum Preparation ... 695
- **Surface Preparation for Specific Types of Damage ... 695**
    - Scratch ... 695
    - Body Filler ... 695
    - Bare Metal ... 696
    - Weld ... 696
    - Rust ... 697
    - Repaint ... 697
    - Blend ... 697
    - Melt ... 698
    - Trim ... 698

Chapter 29

Color Matching ... 701

- **Introduction ... 702**
    - Color Description ... 702
- **Light and Color ... 703**
    - Light ... 703
    - Colors ... 706
    - Comparing Two Colors ... 708
    - Alternate Formulas ... 708
    - Comparison Panel ... 708
    - Plotting a Color ... 711
    - Spectrophotometer ... 712
- **Altering the Refinish Color ... 712**
    - Metallic Orientation ... 712
    - Tinting ... 713
    - Tri-coats ... 716

Chapter 30

Paint Application ... 719

- **Introduction ... 720**
- **Planning the Repair ... 720**
- **Contamination Prevention ... 720**
- **Applying Paint ... 723**
    - Applying Single-Stage Paint ... 723
    - Applying Basecoat/Clearcoat Paint ... 726
    - Applying Tri-coat Paint ... 731
- **Blending Strategies ... 732**
    - Blend within a Repaired Panel ... 732
    - Blending Adjacent Panels ... 733
- **Baking ... 736**
    - Removing Masking Materials ... 737
- **Troubleshooting ... 737**

Chapter 31

Specialty Painting ... 745

- **Introduction ... 746**
- **Plastic Types and Characteristics ... 746**
    - Flexible Plastic Parts ... 746
- **Preparing and Spraying Plastic Parts ... 747**
    - Cleaning ... 747
    - Sanding ... 748
    - Spraying Plastic Parts ... 748
- **Surface Preparation for Specific Types of Plastic ... 749**
    - New, Bare, Non-Rigid Plastic Part ... 749
    - New Primed, Non-Rigid Plastic Parts ... 749
    - Repaired Non-Rigid Plastic Parts ... 750
    - New Rigid Plastic Parts ... 751
    - Repaired Rigid Plastic ... 751
- **Painting Specific Types of Plastic ... 751**
    - Flexible and Semi-Rigid Plastic Parts ... 751
    - Rigid Plastic ... 752
- **Custom Painting ... 752**

Chapter 32

Detailing ... 761

- **Introduction ... 762**
- **Color Sanding ... 762**

- **Buffing** 763
  - Glazing 767
- **Paintless Dent Repair** 767
- **Painted Stripes** 769
- **Installing Pinstripe Tape** 771
- **Adhesive-Attached Plastic Molding** 772
- **Riveted-on Molding Clips** 773
- **Decals** 774
  - Small Decal Installation 774
  - Large Decal installation 774
- **Clean Up** 775
- **Removing Paint Surface Defects** 777
  - Removing Orange Peel 777
  - Dirt Particles 778
  - Runs 778
  - Scratches 779
  - Fade 780
  - Acid Rain 780
  - Chips 781

Section 6
Estimating and Certification

Chapter 33

Estimating 785
- **Introduction** 786
- **Role of the Estimator** 786
  - Working with the Customer 786
  - Working with Insurance Companies 786
  - Identifying Damage 787
  - Specifying Repair Procedures 792
  - Repair vs Replace 793
- **Sourcing Parts** 794
- **Calculating Labor Charges** 798
  - Flat Rate Labor Allowance 798
  - Judgment Labor Allowance 803
  - Surface Prep Allowance 804
  - Plastic Repair Allowance 806
  - Additional Labor Allowance 807
- **Prices** 808
  - Parts Prices 808
  - Material Prices 808
  - Labor Rate 809
- **Additional Charges** 810
  - Disposal Fees 810
  - Sublet Labor 810
  - Sales Tax 810
  - Add-Ons 810
- **Writing Estimates** 810
  - Handwritten Estimate 810
  - Computer-Generated Estimate 811

Chapter 34

ASE Certification 819
- **Introduction** 820
- **What Is ASE Certification?** 820
- **Why Should You Become ASE Certified?** 822
- **How Do I Become ASE Certified?** 822
- **What Are the ASE Tests Like?** 824
  - One-Part Questions 826
  - Two-Part Questions 826
  - Negative Questions 826
  - Incomplete Sentence Questions 826

Chapter 35

Employment Strategies 829
- **Introduction** 830
  - Determining Your Goals 830
  - Working as a Collision Repair Technician 830
  - Payment Method 830
  - Benefits 831
- **Job Hunting** 832
  - The Job Interview 833
  - Evaluating Job Offers 833
- **Succeeding in the Workplace** 833
  - Punctuality/Attendance 834
  - Attitude 834
  - Productivity 834
  - Teamwork 835
  - Honesty 835
  - Continuing Education 835

Appendix 837

Acknowledgments 845

Glossary 846

Index 868

Section 1

Introduction to Collision Repair

Chapter 1. Introduction to Collision Repair
Chapter 2. Safety
Chapter 3. Vehicle Construction
Chapter 4. Fundamentals of Collision Damage
Chapter 5. Welding and Cutting
Chapter 6. General-Purpose Tools and Equipment

Chapter 1

Introduction to Collision Repair

Objectives

After studying this chapter, you will be able to:

- Summarize the typical steps in the collision repair process.
- Compare the various types of body shop ownership.
- Describe the types of jobs available in the collision repair industry.
- Explain the educational opportunities available to those who are interested in a career in collision repair.

Technical Terms

adjusters
aftermarket parts
auto recycler
auto salvage yard
automotive paint store employee
block sanded
body shop estimates
body technician
claim
claim center
combination technicians
comprehensive insurance
dealership body shops
deductible
detailer
detailing
direct repair agreement
estimator
franchise body shop
general automotive repair technician
independent body shop
insurance adjuster
Inter-industry Conference on Autobody Repair (I-CAR)
liability insurance
mechanical aptitude
NATEF task list
National Automotive Technical Education Foundation (NATEF)
National Institute for Automotive Service Excellence (ASE)
nonproduction jobs
OEM parts
office manager
original equipment manufacturer
paint jobber
painter
paintless dent repair technician
parts person
plastic body filler
production job
production manager
rebuilders
refinish technician
roughing out
shop foreman
shop owner
specialty shops
splicing
straightened
structural technician
tear down
topcoat
total loss
undercoats
used parts
wrecker operator

Introduction

The collision repair industry is expected to grow for the foreseeable future. There are approximately 50,000 body shops in the United States. These shops employ about 220,000 workers. For many years, the collision repair industry has suffered from a lack of adequately trained entry-level workers. Each year, there are approximately 50,000 job openings for qualified collision repair professionals.

This chapter will introduce you to the world of collision repair and refinishing. It begins with an overview of the collision repair process. It then details the various job opportunities available in the collision repair industry. The chapter concludes with a look at the educational resources that will help you prepare for a career in collision repair and refinishing.

The Repair Process

To understand the collision repair industry and the opportunities it offers to trained and motivated workers, you should have a basic understanding of the collision repair process. This will allow you to become familiar with the steps involved in repairing a damaged vehicle.

Vehicle damage can range from minor damage, such as a scratch in the paint, to major damage, such as a bent frame. A vehicle that is damaged so badly that repair costs exceed the value of the vehicle is called a ***total loss***. See **Figure 1-1**. An older vehicle, which is generally worth less than a newer vehicle, will be declared a total loss with less damage than its newer counterpart.

Vehicles that are a total loss are usually not repaired by body shops. However, there is a segment of the collision repair industry that buys, repairs, and sells total loss vehicles. The technicians who perform this type of work are called ***rebuilders***.

The collision repair process often starts soon after a vehicle is involved in a collision. If the damaged vehicle is not drivable, it must be towed from the scene of the accident. Damage that can render a vehicle nondrivable includes a leaking radiator, broken steering linkage, or sheet metal that is touching a tire. Additionally, a vehicle should be towed from the scene if it has suffered damage that would make it unsafe to drive, such as a shattered windshield. A nondrivable vehicle is taken by a wrecker, or tow truck, to a storage lot or body shop lot. The vehicle's owner can request that the vehicle be towed to a specific location. **Figure 1-2** shows a wrecker towing a collision-damaged vehicle.

Insurance Claims

Insurance companies pay for most repairs made by body shops. Body shops deal with insurance companies on a daily basis.

There are several types of insurance available. A vehicle's owner can buy ***liability insurance*** to pay for damages caused by the vehicle. For example, if Mr. Wilson has liability insurance coverage and hits Mrs. Smith's vehicle, the insurance company will pay for the damage to Mrs. Smith's vehicle and will also pay for any injuries to the occupants of Mrs. Smith's vehicle. The damage to Mr. Wilson's vehicle will not be paid

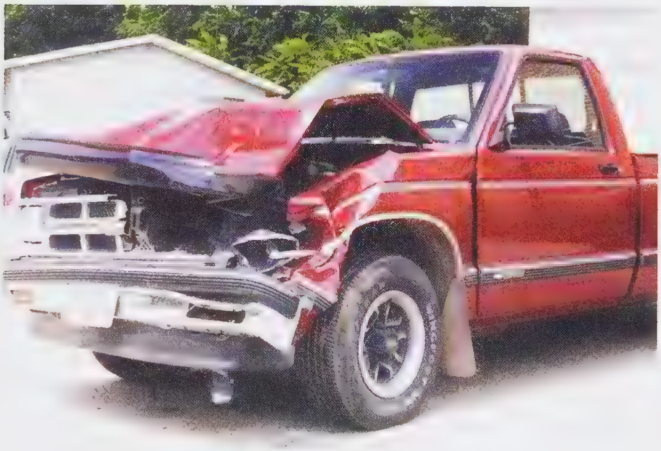


Figure 1-1. *The cost to repair this pickup truck would exceed the value of the vehicle. Therefore, the vehicle is a total loss.*

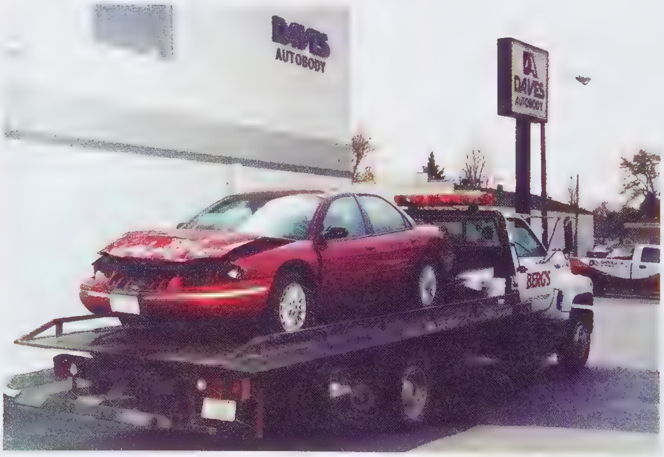


Figure 1-2. *A flatbed wrecker is delivering a damaged vehicle to a body shop.*

for by the liability insurance. If Mr. Wilson wants to fix his vehicle, he must pay for the repairs out of his own pocket. If Mr. Wilson had liability insurance *and* ***comprehensive insurance***, the insurance company would have covered the cost of repairing his vehicle, as well as Mrs. Smith's vehicle.

Comprehensive insurance usually has a deductible. The ***deductible*** is the part of the repair cost the vehicle's owner is responsible for paying. The owner pays the deductible, and the insurance company pays the remaining repair cost. If, for example, Mr. Wilson has $500 deductible comprehensive insurance and the total repair cost is $4500, Mr. Wilson pays $500 and the insurance company pays $4000.

A ***claim*** is made when an insured person suffers a loss and reports this loss to the insurance company. Insurance company employees who handle claims are called ***adjusters***. After the claim is made, the damaged vehicle must be evaluated.

Quite often, an insurance company will tell an insured individual who has made a claim to get two or three ***body shop estimates***. The vehicle's owner then takes the vehicle, if it is drivable, to various body shops. Each body shop evaluates the vehicle and prepares a written estimate of the repair cost. See **Figure 1-3**. The vehicle's owner then gives the estimates to the insurance adjuster.

By getting multiple estimates, the customer essentially completes the comparison-shopping process for the insurance company. The insurance company pays the claim based on the lowest estimate. The insurance company may present a check for the payment of the repairs directly to the vehicle's owner, or it may issue a check that is payable to both the vehicle's owner and the body shop. Both the owner and the body shop must sign the check before it can be cashed. In some cases, the vehicle's owner may decide to keep the money and not repair the vehicle.

Figure 1-3. *A collision technician is preparing an estimate for repairing a damaged SUV.*

If the vehicle is not drivable and has been towed to a body shop lot, that body shop will usually prepare an estimate and get the job unless the vehicle's owner has other plans. In these instances, the insurance company generally requires only one estimate.

Some insurance companies write their own estimates. The vehicle owner is not required to comparison shop for the insurance company. Instead, the owner takes the vehicle to a ***claim center***, which is operated by the insurance company. At the claim center, an insurance adjuster examines the vehicle and writes up an estimate. Once the vehicle's owner is given a check to pay for repairs, the vehicle can be taken to any body shop for repair.

Some insurance companies maintain a list of preferred body shops and will guarantee repairs made by a preferred shop. If the customer chooses a shop that is not on the list, the insurance company will not guarantee the repairs. However, the nonpreferred shop will usually provide some type of warranty.

If an insurance company has a ***direct repair agreement*** with a body shop, the person with a claim can take the damaged vehicle directly to that shop. The body shop will make the repairs and send the bill directly to the insurance company. This streamlined method saves the customer and the insurance company time, and the body shop may see a steady stream of work. The insurance company will periodically check up on the body shop to make sure it is not abusing the direct repair agreement.

With the insurance companies paying most of the bills, it is easy to forget that the vehicle's owner, not the insurance company, is the body shop's customer. The body shop's only goal is to return the vehicle to preaccident condition. The vehicle must look and drive the same as it did before the damage occurred. It must also be as safe as it was originally designed to be. Durability must not be compromised. To be successful, the body shop must make the repair process as quick and painless as possible for the customer. To do this, the shop must be well organized, with a trained and dedicated staff.

After the damaged vehicle has been examined and the estimate, which serves as a blueprint for the repair, has been completed, the actual repair process can begin.

Ordering Parts

Most vehicle repairs require replacement parts. If possible, these parts should be ordered before the vehicle is brought to the shop for repair. It can take several days to obtain parts. If the parts are on hand when the vehicle arrives at the shop, the repairs can proceed without delay. If the vehicle is torn down and the technician has to wait for replacement parts, the vehicle will be in the shop longer.

There are four types of replacement parts: original equipment manufacturer parts, aftermarket parts, used parts, and remanufactured parts. ***Original equipment manufacturer parts***, or ***OEM parts***, are made by the vehicle manufacturer or by the same company that supplied the part to the factory when the vehicle was built. Most parts on vehicles that are less than ten years old can be obtained from the appropriate new car dealership. Some dealerships keep popular collision repair parts in inventory for immediate delivery. Less common or specialized parts must be ordered. Some dealerships do not stock collision repair parts. Nevertheless, most parts can be obtained within a week. An OEM part is shown in **Figure 1-4**.

Aftermarket parts are made by a company other than the one that supplied the parts when the vehicle was manufactured. Aftermarket parts usually cost less than OEM parts. These parts may be in stock, or they may have to be ordered. Aftermarket parts may also be obtained by mail order or over the Internet. Automotive paint wholesale/retail stores, which sell collision repair equipment and refinish materials, may also sell aftermarket parts. Aftermarket parts should be checked for proper fit before they are painted. **Figure 1-5** shows an aftermarket part.

Used parts are taken off total loss vehicles in a salvage yard. Used parts are normally sold as assemblies. An assembly is a major part with the related components attached to it. For example, a used fender will generally include the moldings and fender liner. When buying OEM or aftermarket parts, these items would have to be obtained separately and at an additional cost. Used parts may have damage or they may have been previously repaired. Some salvage yards will make a nationwide search for used parts. Used parts for late-model vehicles—those that are only one or two years old—may be in short supply. A used part is shown in **Figure 1-6**.

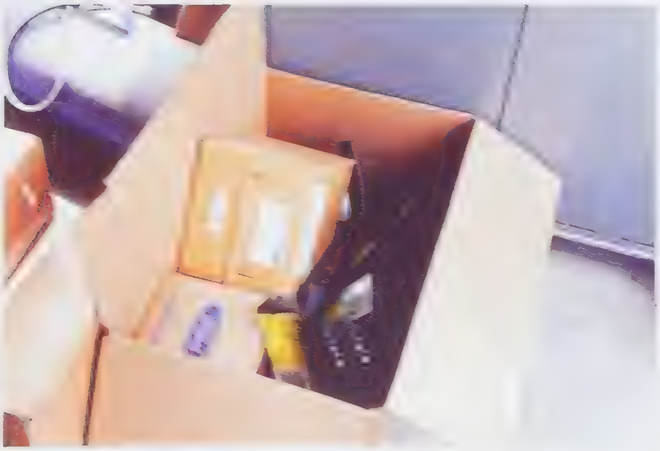


Figure 1-4. *This box contains OEM parts. These particular parts are from Ford.*

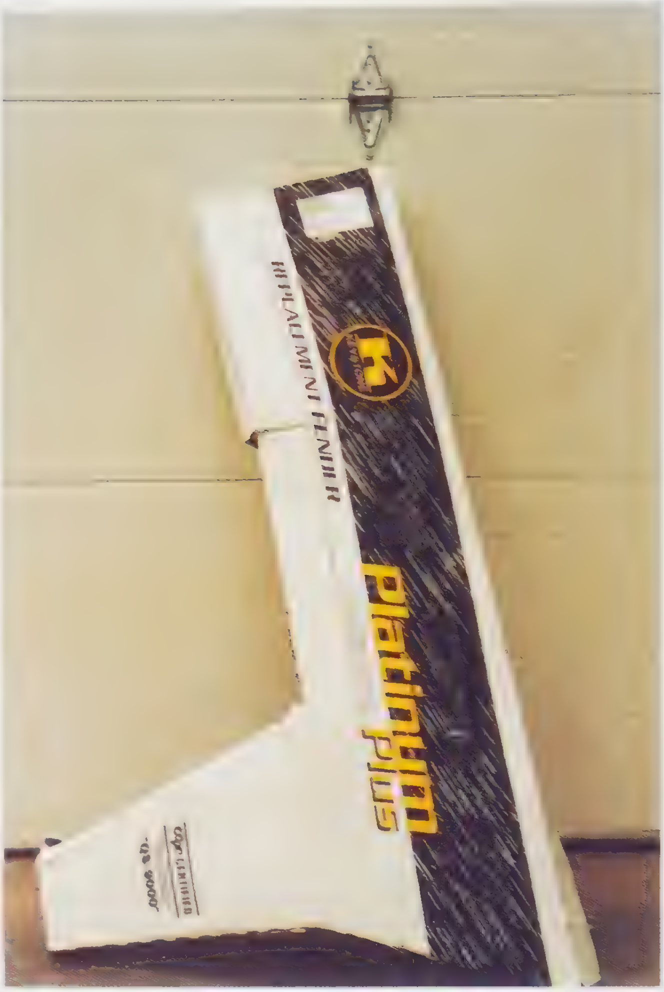


Figure 1-5. *This box contains an aftermarket fender. Note that it was not made by an automobile manufacturer.*

WORKING GREEN

In addition to being economical, installing used parts is environmentally responsible. If automotive parts are not reused, they will likely end up in a landfill. Additionally, choosing used parts reduces the pollution associated with the manufacture of new components.

A ***remanufactured part*** is a used part that has been restored to like-new condition. The remanufactured part will generally have a warranty. Examples of remanufactured parts are alloy wheels, chrome bumpers, bumper covers, and mechanical parts, such as alternators and starters.

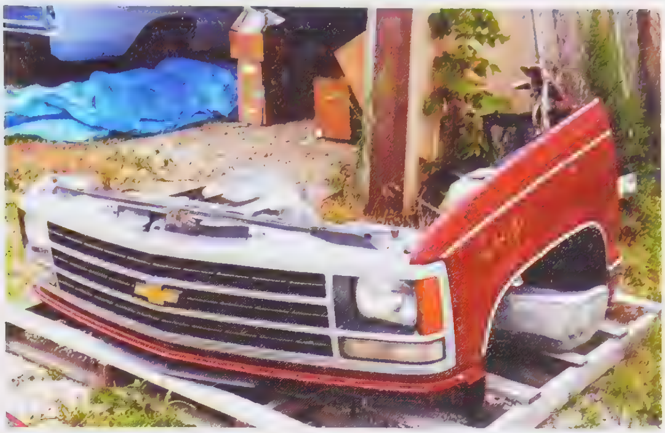


Figure 1-6. *This used left fender, radiator support assembly, and front bumper were delivered to the body shop on a pallet.*

Body Repairs

When the vehicle arrives at the shop, it must be dismantled to replace parts and access to hidden damage, **Figure 1-7.** This process is known as ***tear down***. During tear down, additional damage is sometimes found. The collision repair technician must report this damage to the shop foreman. Additional parts may be needed to complete the repair, and it is best that the shop discover this early to prevent delays in the repair process.

Structural repair involves taking measurements to pinpoint the damage, determining a course of action, immobilizing the vehicle, and pulling to align structural components. Proper measuring is critical. The technician must locate all damage in order to repair it.

Once the vehicle is measured, the technician can decide on a course of action. By thinking through the repair, the technician can avoid unnecessary work and backtracking.

The vehicle must be immobilized before pulls can be made. Clamps or chains are used to hold the vehicle in place. With the vehicle immobilized, hookups are attached to the damaged area and structural components are pulled into proper alignment. See **Figure 1-8**. Measurements are taken during and after the pulls to check the progress. It may take several hookups and pulls to align the structure.

Badly damaged panels are often replaced. After the damaged panel has been removed, the replacement panel is carefully aligned and then welded, bonded, or bolted in place, **Figure 1-9**. Alignment involves more than just positioning the part. It also includes checking related parts to make sure they fit properly.

Sometimes only a portion of a damaged panel is replaced. This procedure is called ***splicing***. The proper splice location is identified and the damage is cut out. The replacement part is welded at the splice joint.

Lightly damaged panels can often be repaired, or ***straightened***. However, an inexpensive, easily replaced panel, such as a fender, may be replaced even if it is only lightly damaged. This is because the repair cost would exceed the replacement cost. Steel panel repair involves examining the damage, removing parts that would impede the repair, roughing out the damage, filling, and sanding. Examining the damage is important. You must find all the damage if you are to repair it properly. After assessing the damage, you must remove any parts that will interfere with the repair. In some cases, the back of a panel must be accessed to repair damage. For example, a trunk liner can be removed to reach the back of a dented quarter panel. The body damage can be tapped out with

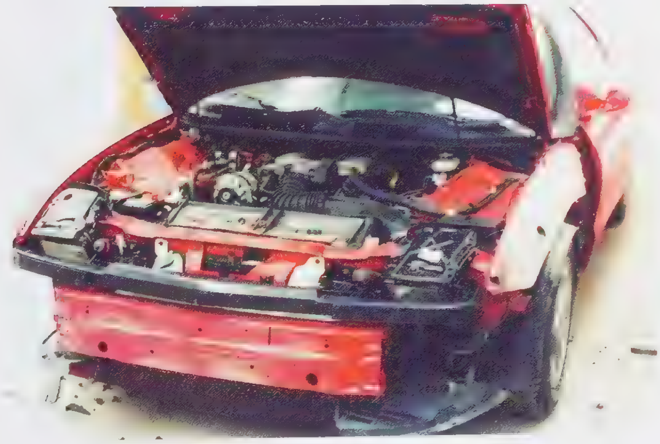


Figure 1-7. *Tear down on this vehicle, which was hit in the left front corner, included removing the fender and front bumper cover.*

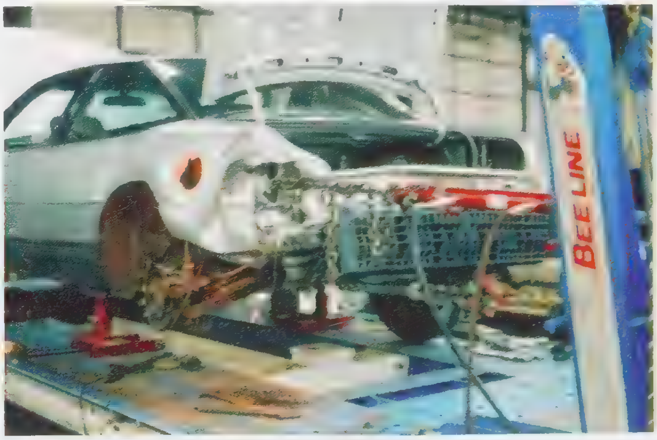


Figure 1-8. *This unibody vehicle was involved in a collision that caused structural damage. Repair involves mounting the vehicle on a frame machine and pulling the damaged panels into alignment.*

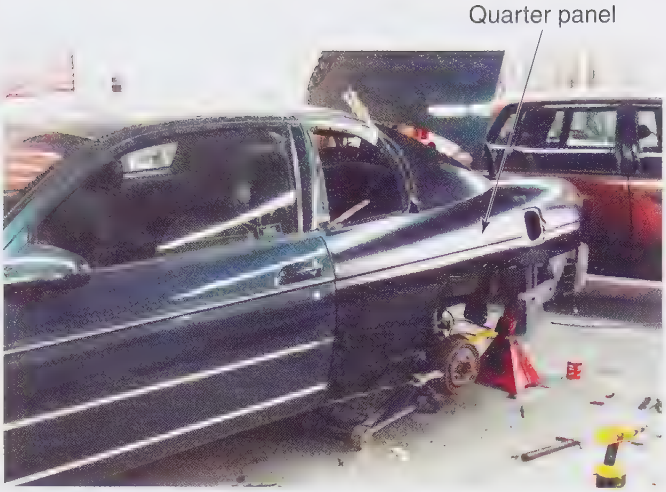


Figure 1-9. *Adhesives were used to secure this replacement quarter panel.*

a hammer and dolly. This method of removing damage is commonly referred to as ***roughing out***.

When the metal has been moved to within 1/8" of its proper location, the remaining damage can be filled. ***Plastic body filler*** is applied to the surface of the damaged panel to achieve the proper contour. After the body filler cures, it is sanded, completing the metal repair. See **Figure 1-10**. Damaged plastic parts can be shaped, filled, bonded, or welded.

Mechanical Repairs

The collision repair technician must sometimes repair or replace mechanical and electrical components damaged in a collision. For example, the air conditioning system condenser is often damaged in a front-end collision and must be replaced. Even if the condenser is not damaged, it must sometimes be moved to access damaged components. After air conditioning system components are replaced, the system must be recharged. See **Figure 1-11**.

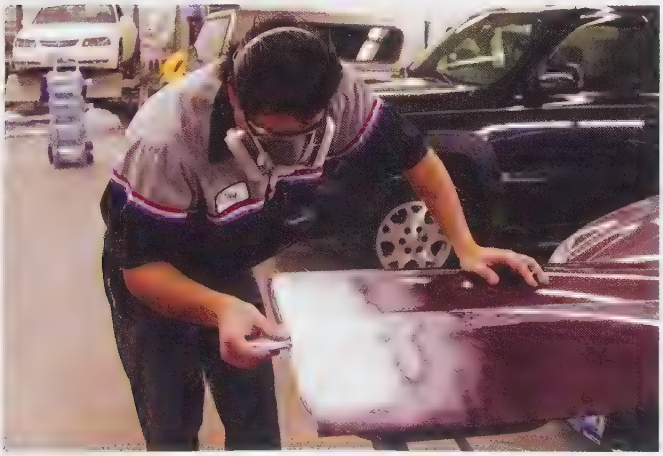


Figure 1-10. *This technician is sanding cured body filler on a damaged panel.*

The radiator is another component that is frequently damaged in a front-end collision. If the radiator is to be removed, the coolant must be drained from the cooling system. The coolant is replaced after the radiator is reinstalled. A collision that damages the air conditioning condenser and radiator will often damage the cooling fan. After repairs are made, the air conditioning and cooling systems should be checked to make sure they function correctly.

The air bags can be triggered by a front-end collision. Replacing the air bags involves assessing the damage, replacing the parts that need to be replaced, and verifying system operation. See **Figure 1-12**. The seat belts must also be checked for damage.

Steering and suspension systems must be carefully inspected after a collision. A wheel that is not positioned

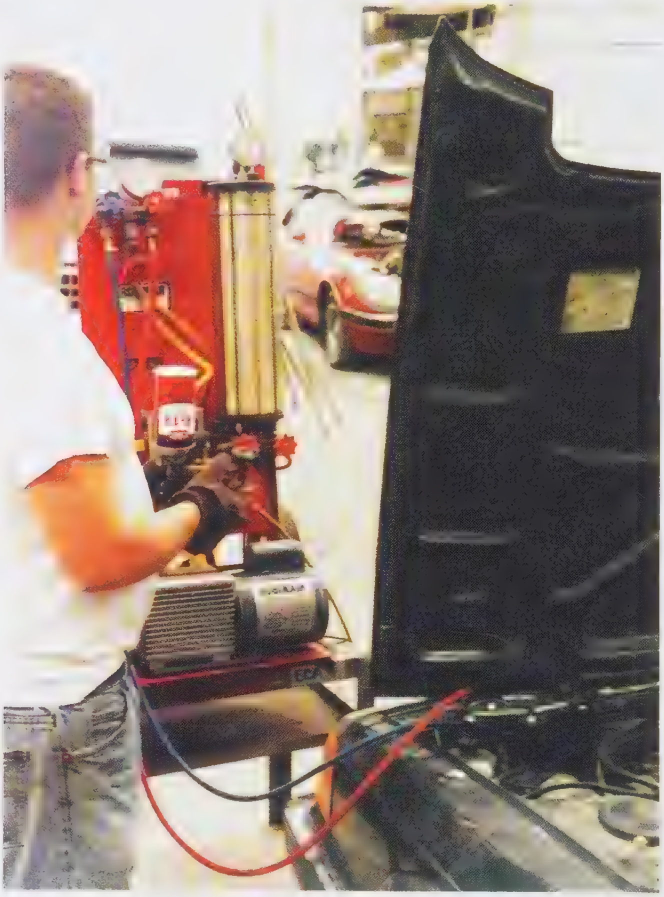


Figure 1-11. *The air conditioning system compressor was damaged when this vehicle was involved in a frontal collision. This technician is recharging the air conditioning system.*

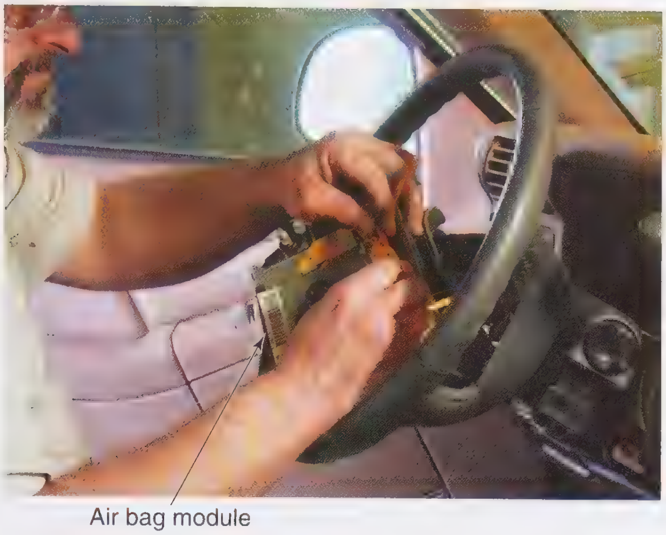


Figure 1-12. *The air bag deployed when this vehicle was involved in a collision. The technician is replacing an air bag module.*

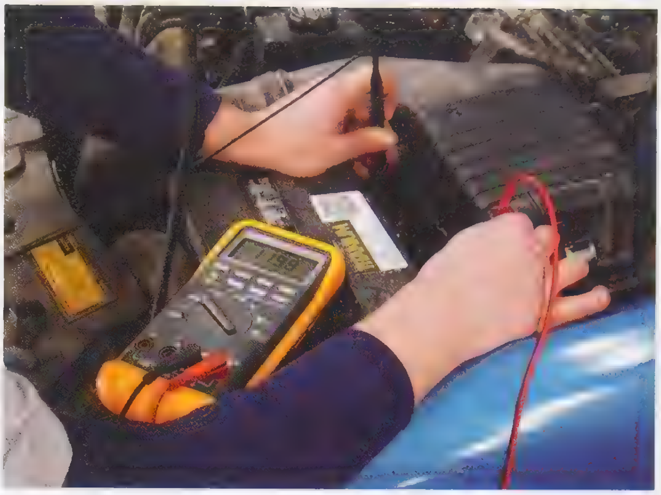


Figure 1-14. *This technician is checking battery voltage on a damaged vehicle.*

properly means that one or more parts are damaged. Repair involves removing damaged parts, installing new parts, and aligning the steering and suspension system components. The alignment will adjust the components' position so the vehicle will handle and steer properly, **Figure 1-13**.

Electrical system parts, such as the headlights, marker lights, taillights, and horn, can be damaged in an accident. Wires may also be cut. Electrical system repair generally requires the diagnosis and repair or replacement of damaged parts. See **Figure 1-14**.

The brake system may be damaged by an impact on a wheel. The antilock brake system components are the most vulnerable brake system parts. Repair requires diagnosis and replacement of damaged parts.

Refinishing

The paint is the part of the repair that is most evident to the customer, and therefore, the refinish should look just like the original paint. The paint repair should not be noticeable. Refinishing involves two steps—applying undercoats and applying topcoats.

Undercoats are layers of paint designed to bind with bare metal, prevent rust, and fill scratches. When the undercoats are sprayed, the parts of the vehicle that will not be painted should be protected by masking.

Once the undercoats are applied and cured, the repair is ***block sanded***. Block sanding flattens the repair area, making it the same height as the surrounding paint. See **Figure 1-15**.

Figure 1-13. *A wheel alignment is often the last repair done before a vehicle is cleaned up for delivery.*

Figure 1-15. *The undercoat is sanded to remove imperfections.*

The ***topcoat*** covers the undercoat. The customer will see the topcoat. Any imperfections in the undercoat or body filler will show up in the topcoat. The topcoat is sprayed over the undercoat and blended into the paint on adjacent panels, **Figure 1-16**. Many late-model vehicles use a two-stage topcoat. The vehicle is first painted with a color basecoat and then painted with a clear coat. When repairing this type finish, both the basecoat and the clear coat must be applied to achieve an acceptable repair.

Reassembly

After painting, the vehicle may need to be reassembled. Some parts are painted off the vehicle and installed after the paint has cured. See **Figure 1-17**. Any parts removed before painting are reinstalled during the reassembly phase.

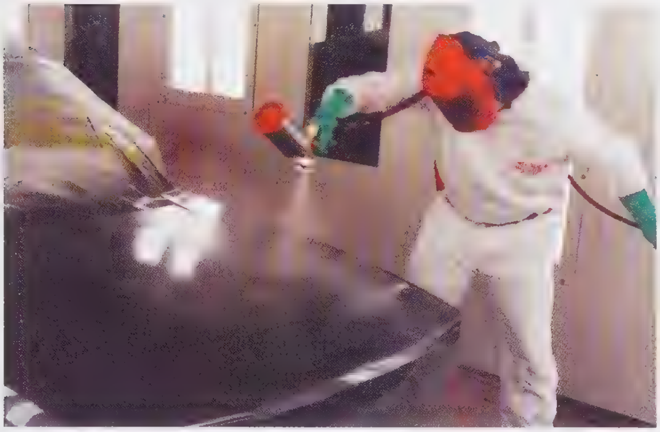


Figure 1-16. *A durable topcoat is applied over the undercoat.*

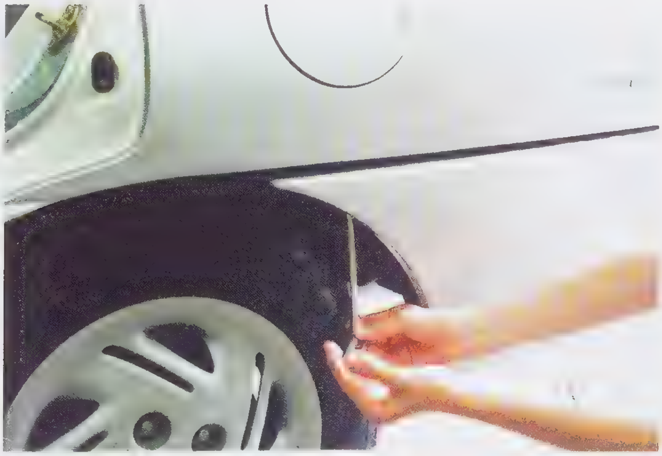


Figure 1-17. *The rear bumper is being installed on this vehicle during reassembly.*

Detailing

A repaired vehicle is usually detailed before it is delivered to the owner. ***Detailing*** involves sanding, buffing, and washing. Sanding with fine sandpaper and buffing can remove topcoat imperfections, **Figure 1-18**. Washing removes dust and other contaminants from the vehicle. If necessary, stripes or decals are applied during the detailing phase. Detailing is the last step in collision repair. Some shops also clean the inside of the vehicle before releasing it to the owner.

Body Shop Types

There are many types of body shops, or collision repair shops, ranging from small independent shops to large dealer-owned facilities. An ***independent body shop***, **Figure 1-19**,

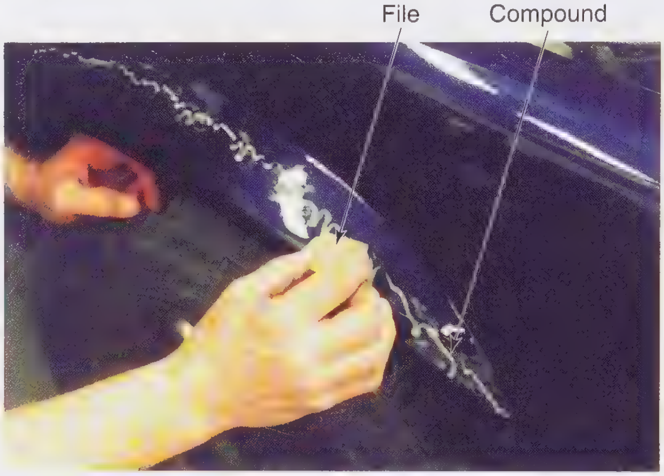


Figure 1-18. *Imperfections in the topcoat are removed during the detailing phase. This technician is using a small file to remove a run in the paint.*

Figure 1-19. *This small independent collision repair shop has only three employees.*

is a stand-alone operation that is generally owned by one or two individuals. The size of the shop can be gauged by the number of employees who work there or the amount of the repair work it performs each year. A small independent shop may be unable to provide health insurance, paid vacations, or retirement benefits for its employees.

A ***franchise body shop*** is part of a large regional or national organization,, **Figure 1-20**. One company may own several body shops under a single name, or a body shop owner may purchase a franchise operation from the larger organization. Since it is part of a bigger organization, a franchise operation may be able to offer its employees more benefits than an independent shop.

In addition to selling new and used vehicles, many full-service dealerships provide collision repair services, **Figure 1-21**. ***Dealership body shops*** often perform warranty work. If a customer's vehicle has a body or paint problem that is covered under warranty, the dealership body shop will fix the problem. Benefits are usually available to employees of dealerships.

Specialty shops include restoration, customizing, and repaint shops. Restoration and customizing shops are often attractive to students. Both of these types of shops require people who pay precise attention to detail. A specialty shop is shown in **Figure 1-22**. This type of shop can be independently owned, or it may be part of a franchise organization.

Collision Repair Industry Jobs

There are a variety of jobs available in the collision repair industry. The employees who work in these jobs can be grouped into two broad categories: body shop employees and body repair support employees.

Body Shop Employees

The body shop employees work in a body shop. These employees will have either a production job or a nonproduction job. In a ***production job***, the employee performs the actual repairs. ***Nonproduction jobs*** involve tasks that support the production jobs, such as writing estimates and obtaining parts.

Production Jobs

Production jobs are directly involved in vehicle repair. There are many production jobs available in a typical collision repair shop. Many of these jobs are described in the following section.

Maaco
MAACO

Figure 1-20. *This franchise body shop is part of a large organization.*

Figure 1-21. *This body shop is part of a large dealership.*

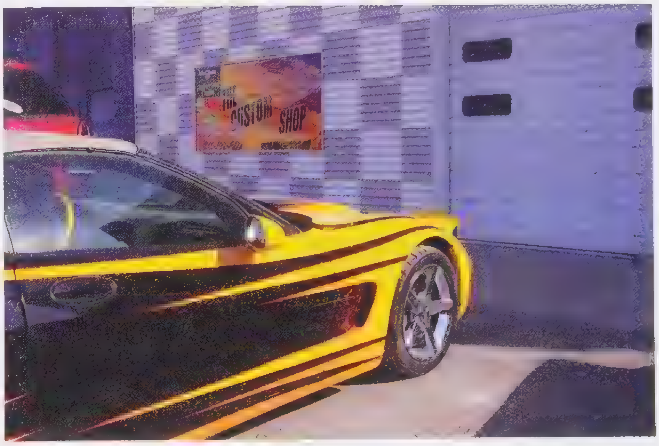


Figure 1-22. *Automotive specialty shops, such as this custom paint shop, offer opportunities for auto body technicians.*

The ***body technician*** repairs and replaces damaged panels. The skills needed for this position include welding, panel alignment, plastic repair, and dent repair. A body technician is expected to have hand and power tools.

A ***refinish technician***, or ***painter***, must be proficient in spray gun usage, block sanding, color matching, and buffing. The tool requirements for this position are minimal. Some shops provide spray guns and other refinishing tools.

A ***structural technician*** diagnoses and repairs structural damage. A structural technician must understand the importance of returning the vehicle to pre-accident condition. This type of technician must be able to weld, remove parts, immobilize a vehicle, and hook up pulling equipment. A structural technician may be required to have appropriate hand and power tools.

The ***general automotive repair technician*** makes mechanical repairs to damaged vehicles, such as replacing air conditioning, drive train, or suspension system components. This technician should be able to align steering and suspension systems, and recharge air conditioning systems. A general repair technician must have hand and power tools.

A ***detailer*** cleans repaired vehicles before delivery. Detailers may also apply decals and buff paint, but they are not commonly required to have tools.

Many shops hire one or more technicians to perform each of the above jobs. Other shops combine these jobs. For example, body, frame, and mechanical repairs are done by one group of technicians, while refinishing and detailing is done by another group. Some shops hire ***combination technicians***, who perform all types of repairs on damaged vehicles. See **Figure 1-23**.

All production jobs require good eye-hand coordination and excellent mechanical aptitude. ***Mechanical aptitude*** involves the intrinsic ability to take things apart and put them back together again. Not all individuals interested in cars have this ability. Production jobs require the technician to stay with a task until it is completed. Production jobs also require attention to detail. Collision repair is a series of steps. If each step is performed correctly, the repair will turn out well. If a step is skipped or performed poorly, the result will be poor.

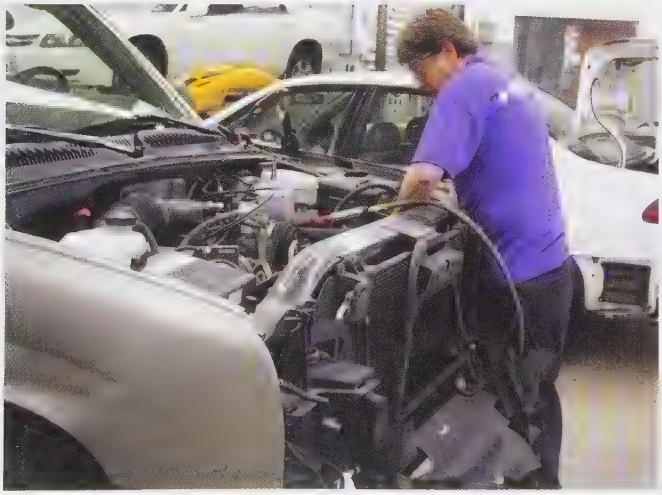


Figure 1-23. *A combination technician is making mechanical repairs on a damaged vehicle.*

Nonproduction Jobs

Nonproduction jobs support the production jobs. A large body shop may employ people in several specialized nonproduction positions.

The ***shop owner*** is in charge of the shop. Some owners are part of the nonproduction team. Others are not involved in the business at all. Many technicians aspire to be a shop owner.

The ***production manager***, or ***shop foreman***, is responsible for ordering parts, scheduling work, talking to customers, and evaluating their technicians' performance. This person must have strong organizational skills, as well as an in-depth knowledge of the collision repair process. The production manager keeps work flowing through the shop. If hidden damage is discovered, the production manager often obtains the needed parts.

An ***estimator*** is often the first body shop employee the customer encounters. Therefore, this person must have good people skills. The customer should feel comfortable and confident that the shop can make the necessary repairs. An estimator must have extensive knowledge of vehicle repair, as well as adequate computer skills.

The ***parts person*** is responsible for ordering parts and supplies. This person will check in the parts as they are received and distribute the parts as the jobs arrive in the shop. The parts person also handles the return of incorrectly shipped parts.

The ***office manager*** supervises the estimator and parts personnel, and is responsible for accepting payment from the customer. This person is also responsible for releasing the repaired vehicle to the customer.

Some shops operate a wrecker, or tow truck, service. Usually the ***wrecker operator*** is available twenty-four hours a day. The wrecker operator must have good people skills, as well as knowledge of how to recover and tow vehicles.

Body Repair Support Positions

Employees in body repair support positions perform tasks the body shop personnel do not, or they serve as a liaison between the body shop and the insurance company. These individuals generally do not work in the body shop.

Insurance Adjuster

The ***insurance adjuster*** is an employee of the insurance company. The adjuster's job is to write or review estimates and meet the insurance company's obligation to the customer. Part of the insurance adjuster's job is to minimize the cost of claims. Some insurance adjusters are former collision repair technicians. An adjuster must have good estimating and communications skills.

Automotive Paint Store Employee

An ***automotive paint store employee***, also called a ***paint jobber***, sells paint and supplies to body shops. Most body shops use a specific brand of paint. There is a close relationship between the body shop and the automotive paint store. The paint store employees must be able to answer technical questions about the paint and anticipate the body shop's supply needs. Automotive paint store employees stock supplies, mix paint, and deliver paint and supplies to body shops. Automotive paint store employees must be able to communicate effectively with customers.

Auto Salvage Yard Employee

An ***auto salvage yard***, or ***auto recycler***, buys wrecked vehicles and sells parts. Customers of salvage yards include body shops, mechanical repair shops, and the general public. Auto salvage yard employees must know how to dismantle vehicles in the correct manner. Auto salvage yard employees must also have good mechanical skills.

Paintless Dent Repair Technician

If a body shop does not employ a technician with the skill to remove small dents without damaging the paint, the shop may call in a ***paintless dent repair technician***. These independent technicians have been trained to identify, access, and carefully pry out small dents, such as door dings and hail dents. A paintless dent repair technician must have excellent eye-hand coordination and good mechanical skills.

Automotive Glass Technician

Many body shops do not perform vehicle glass removal and replacement. Automotive glass technicians, employed by independent glass shops, are called into body shops to remove and replace windshields, side glass, and back glass. An automotive glass technician must pay attention to detail and possess good mechanical skills.

Additional Workers

There are several other workers involved in body shop support: dealership part store employees, aftermarket part store employees, wrecker drivers, graphics technicians, and radiator/condenser technicians. The parts store employee must be able to order and deliver parts. Computer skills are also necessary. A graphics technician installs decals, transfers, and stripes. This requires good eye-hand coordination. A radiator/condenser technician repairs damaged radiators and condensers. This technician must have good mechanical aptitude.

Educational Opportunities

All collision repair and refinishing jobs require training. As vehicles become more complex, the need for training will increase. A technician should obtain as much education as possible. Education should be a continuous process throughout a technician's career.

WORKING SMART

Take advantage of the educational opportunities available to you. The skills needed to become a successful collision repair technician are developed through practice and instruction.

Some high schools offer one- or two-year collision repair programs. Other programs may include one year of auto mechanics and one year of collision repair. See **Figure 1-24**.

Community colleges frequently offer collision repair certificates to students who complete a one-year program. The basics of collision repair can generally be taught in one year. A degree in collision repair from a community college will require two years of study. Students often work part-time in a body shop while attending school. This combination gives the students an edge when they enter the industry full time.

Technical schools are private, for-profit educational facilities. These schools need large enrollments to stay in business. They advertise heavily and will generally help students find jobs.

Some schools partner with vehicle manufacturers to develop effective training programs. For example, the Toyota Technical Education Network (T-TEN) and General Motors' Body Service Educational Program (BSEP) offer students collision repair training in a work-study environment. In these programs, each student is sponsored by a vehicle dealership. The student works at the dealership body shop for a period of time and then attends classes at the school.

Figure 1-24. *This student is practicing her spray technique in a collision repair and refinishing training program.*

ASE

The ***National Institute for Automotive Service Excellence (ASE)*** is an organization that tests and certifies auto body technicians, as well as general repair technicians. ASE tests are given twice each year at locations throughout the United States. Auto body certification tests are offered in four areas—painting, nonstructural repair, structural repair, and mechanical repair. To receive certification in any of these areas, you must pass the corresponding test and have at least two years of related work experience. To be an ASE-certified master auto body technician, you must pass all four tests and meet the experience requirements. An auto body estimating test is also available.

In addition to certifying technicians, ASE also accredits collision repair training programs. The ***National Automotive Technical Education Foundation (NATEF)*** evaluates automotive training programs against standards developed by the collision repair industry and recommends qualifying programs for ASE accreditation. An ASE-accredited program must meet rigid standards and undergo periodic inspections. An accredited program must also follow an approved curriculum that is correlated to the ***NATEF task list***. This task list is compiled by NATEF to help ensure that students gain the necessary skills from the training program.

I-CAR

The ***Inter-Industry Conference on Auto Collision Repair (I-CAR)*** trains technicians who are already in the industry. I-CAR was formed to educate workers about the proper way to repair unibody vehicles. Knowledgeable instructors teach I-CAR classes at locations throughout the United States. A wide variety of courses are available. I-CAR also certifies technicians in MIG welding for collision repair. In addition to training auto body technicians, I-CAR guides collision repair support office personnel. I-CAR has established uniform repair standards that serve as a benchmark for proper vehicle repair.

Summary

- The collision repair industry is expected to grow for the foreseeable future.
- The vehicle's owner is the body shop's customer.
- The insurance company pays most collision repair costs.
- Body shops and insurance companies can write estimates.
- Parts can be either OEM, aftermarket, used, or remanufactured.
- Body repair includes tear down, frame repair, panel straightening, and panel replacement.
- Refinishing includes spraying undercoats and topcoats.
- Mechanical repair includes replacing steering and suspension parts, as well as restraint system, air conditioning, and cooling system parts.
- Body shop jobs may be production or nonproduction.
- Educational opportunities may be found in high schools, colleges, or trade schools.
- Body shop types include independent, dealership, franchise and specialty
- Production jobs include body technician, refinish technician, structural technician, mechanical repair technician and combination technician.
- Nonproduction jobs include shop owner, production manager, estimator, parts person, office manager, and wrecker operator.
- Body repair support jobs include insurance adjuster, automotive paint store employee, auto salvage yard employee, automotive glass technician and paintless dent repair technician.

Review Questions

Please do not write in this textbook. Place your answers on a separate sheet of paper.

1. A vehicle is a(n) ______ if it is damaged so badly that repair costs exceed the value of the vehicle.
2. Name three types of damage that could render a vehicle nondrivable.
3. Most body shop repairs are paid for by insurance companies. True or False?
4. The part of the repair cost that the vehicle's owner is responsible for paying is the ______.
5. Why do some insurance companies require the customer to get two or three repair estimates?
6. If an insurance company has a(n) ______ agreement with a body shop, the shop repairs the damaged vehicle and sends a bill to the insurance company.
7. Because the insurance company pays for the repair, the insurance company, not the vehicle's owner, is the body shop's customer. True or False?
8. A(n) ______ part is a used part that has been restored to like-new condition.
9. ______ is applied to damaged metal to raise the surface to its proper contour.
10. After steering and suspension parts are installed, the components must be ______ so the vehicle will handle and steer properly.
11. Once the undercoat has cured, it should be ______ to make the repair area the same height as the surrounding paint.
12. The customer sees the topcoat. True or False?
13. Sanding and buffing to remove topcoat imperfections is done during the ______ stage of body repair.
14. ______ and ______ are performed during the detailing stage to remove topcoat imperfections.
15. ______ body shops often perform warranty work.
16. The ______ technician is responsible for all repairs on a damaged vehicle.
17. Explain the difference between production jobs and nonproduction jobs.
18. All auto collision repair jobs require training. True or False?
19. Insurance company adjusters align panels and adjust latches and hinges. True or False?
20. Explain what *NATEF* does.

ASE-Type Questions

1. Technician A says that the collision repair industry is expected to grow for the foreseeable future. Technician B says that there is a surplus of trained entry-level workers in the collision repair industry. Who is right?
   (A) A only.
   (B) B only.
   (C) Both A and B.
   (D) Neither A nor B.
2. Technicians who repair total-loss vehicles are called ______.
   (A) recyclers
   (B) rebuilders
   (C) reclaimers
   (D) restorers
3. Technician A says that a repaired vehicle must look and drive the same as it did before it was damaged. Technician B says that a repaired vehicle must be as safe as it was originally designed to be. Who is right?
   (A) A only.
   (B) B only.
   (C) Both A and B.
   (D) Neither A nor B.
4. Each of the following is a type of replacement part EXCEPT:
   (A) generic.
   (B) OEM.
   (C) aftermarket.
   (D) used.
5. Technician A says that hidden damage is sometimes found during teardown. Technician B says hidden damage should be reported to the shop foreman so additional parts can be ordered. Who is right?
   (A) A only.
   (B) B only.
   (C) Both A and B.
   (D) Neither A nor B.
6. Structural repair involves each of the following steps EXCEPT:
   (A) taking measurements.
   (B) immobilizing the vehicle.
   (C) determining a course of action.
   (D) applying body filler.
7. Replacing a portion of a damaged panel is known as ______.
   (A) bonding
   (B) matching
   (C) splicing
   (D) binding

8. Removing damage by tapping it out with a hammer and dolly is often referred to as ______.
   (A) contouring
   (B) roughing out
   (C) forming
   (D) tapping out
9. Technician A says that body filler is applied when the damaged metal is within 1/2" of its proper location. Technician B says body filler must be allowed to cure before it can be sanded. Who is right?
   (A) A only.
   (B) B only.
   (C) Both A and B.
   (D) Neither A nor B.
10. Technician A says that the air conditioning condenser is often damaged in a front-end collision. Technician B says that the cooling fan is often reused when the condenser and radiator are damaged in a collision. Who is right?
    (A) A only.
    (B) B only.
    (C) Both A and B.
    (D) Neither A nor B.
11. The undercoat is designed to do each of the following EXCEPT:
    (A) prevent rust.
    (B) fill scratches.
    (C) bind with bare metal.
    (D) provide a suitable base for the clear coat.
12. Each of the following is a body shop production job EXCEPT:
    (A) structural technician.
    (B) painter.
    (C) body technician.
    (D) estimator.
13. The intrinsic ability to take things apart and put them back together is known as ______.
    (A) eye-hand coordination
    (B) mechanical aptitude
    (C) logic analysis
    (D) reasoning capacity
14. Technician A says the shop foreman is responsible for keeping work flowing through the shop. Technician B says that the office manager is responsible for accepting payment from the customer. Who is right?
    (A) A only.
    (B) B only.
    (C) Both A and B.
    (D) Neither A nor B.
15. Each of the following statements about I-CAR is true EXCEPT:
    (A) I-CAR was formed to educate workers about the proper ways to repair unibody vehicles.
    (B) I-CAR certifies technicians in MIG welding for collision repair.
    (C) I-CAR standards form a benchmark for proper vehicle repair.
    (D) I-CAR evaluates automotive training programs against standards developed by the collision repair industry.

Chapter 2

Safety

Objectives

After studying this chapter, you will be able to:

- Recognize the hazards encountered in the collision repair shop.
- Demonstrate the proper use of the protective gear worn in the collision repair shop.
- Describe the safe working practices associated with the various tasks performed in the collision repair shop.
- Identify the hazardous wastes generated in the collision repair shop.
- Explain how the amount of waste generated in the shop can be minimized.
- Describe the role of government agencies in regulating collision repair shop wastes.

Technical Terms

acute hazard
air change
atomized
carbon monoxide
cartridge-type respirator
chronic hazard
cradle-to-grave
dust mask
Environmental Protection Agency (EPA)
fire extinguishers
generator
good housekeeping
make up air
material safety data sheet (MSDS)
Occupational Safety and Health Administration (OSHA)
reduction
repetitive stress injury
respirator
right-to-know laws
safety glasses
safety goggles
sensitization
supplied-air respirator
tension
transfer efficiency
volatile liquid
volatile organic compounds

Introduction

To work safely in the collision repair shop, technicians must recognize the dangerous tasks and materials encountered on the job. Technicians must know how to protect themselves and their fellow workers from these dangers. They must also take steps to protect the vehicles in the shop and the shop itself.

Collision Repair Shop Hazards

There are many hazards encountered in the collision repair shop. The technician must be aware of these hazards and take appropriate steps to minimize the potential dangers associated with them. The following sections highlight the most common hazards found in the collision repair shop.

Both chronic and acute hazards are encountered in the shop. A ***chronic hazard*** can cause long-term health damage, usually as the result of repeated or prolonged exposure to the hazard. For example, breathing sanding dust will gradually fill the air sacs in a technician's lungs. Similarly, breathing low levels of solvent vapors or mists over a long period of time can cause liver, kidney, or brain damage. The same damage can occur if solvents are allowed to repeatedly contact the skin over a long period. Solvents can be absorbed through the skin, or they can enter the skin through a cut. By either means—breathing in the vapors or allowing liquid solvents to contact the skin—the chemicals enter the bloodstream and travel to various organs.

Chemicals may also be accidentally ingested. For example, if the technician does not wash his hands before eating, the paint on his hands may be ingested along with food.

A neurotoxin is a chemical that can cause chronic damage to the central nervous system. Symptoms of central nervous system damage include problems with vision, coordination, and judgment. Lacquer thinners and enamel reducers are examples of common neurotoxins.

Blood toxins inhibit the ability of red blood cells to carry oxygen. Exposure to a blood toxin may make breathing difficult. Blood toxins include hardeners and clearcoats. Liver toxins, such as lacquers and urethanes, cause long-term liver damage. Reproductive toxins cause damage to the genetic information, or DNA, passed from parent to offspring. Birth defects, which can range from negligible to debilitating, result from damaged DNA. Reproductive toxins include acrylic lacquers and urethanes. Carcinogens are cancer-causing agents. There are many types of cancer, but all cancer is unregulated cell growth. Some cancers cause tumors. Sealers and any other paint products that contain silica are possible carcinogens.

An ***acute hazard*** is a hazard that causes an immediate (or within a few hours) reaction. A single exposure to an acute hazard can cause health problems. These problems may or may not be permanent. For example, an unprotected individual will become sensitized to isocyanate vapor or mist. This person will then suffer an acute reaction whenever even a slight amount of isocyanate is present in the air. The acute reaction to isocyanates causes asthma-like symptoms. A sensitized individual should not work in a collision repair shop because further exposure to even small amounts of isocyanates will cause progressively more severe reactions.

Fire Hazards

Collision repair and refinishing operations and materials can easily cause a fire. Fire is one of the most devastating accidents that can occur in a collision repair shop.

Good housekeeping and careful use of equipment will help prevent fires. ***Good housekeeping*** involves keeping the work area clean and well organized. This includes throwing away used masking paper, wiping cloths, cardboard packaging, and other flammable substances. Never allow flammables to pile up in a corner. Store them in an appropriate container until they can be disposed of properly. See **Figure 2-1**.

Use caution when lighting a torch or using a MIG welder. Remove combustibles from the work area and be observant. Before welding, make sure the back of the panel being repaired is accessible. This will allow you to see if undercoat or insulation catches fire. If there is smoke rising out of a panel or cavity, there is likely a fire within the cavity. When this occurs, take appropriate steps to extinguish the fire. Never smoke in the paint storage, mixing, or spraying areas.

It is much easier to prevent a fire than it is to put it out. However, if a fire does start, be aware that the smoke from a fire is a more frequent cause of death than the heat of a fire. The smoke can be toxic and suffocating. Breathing the smoke may cause you to lose consciousness. Never enter a smoke-filled room to put out a fire. Doing so will put you at great risk. Instead, get out of the building and call the fire department.

Some shops are equipped with a sprinkler system to help extinguish fires. The system detects the heat of a fire and sprays the shop with water, extinguishing the flame.

Fire Extinguishers

Small fires can be put out with fire extinguishers. A fire needs combustible material, heat, and oxygen in order to burn. If you remove one of these elements, the

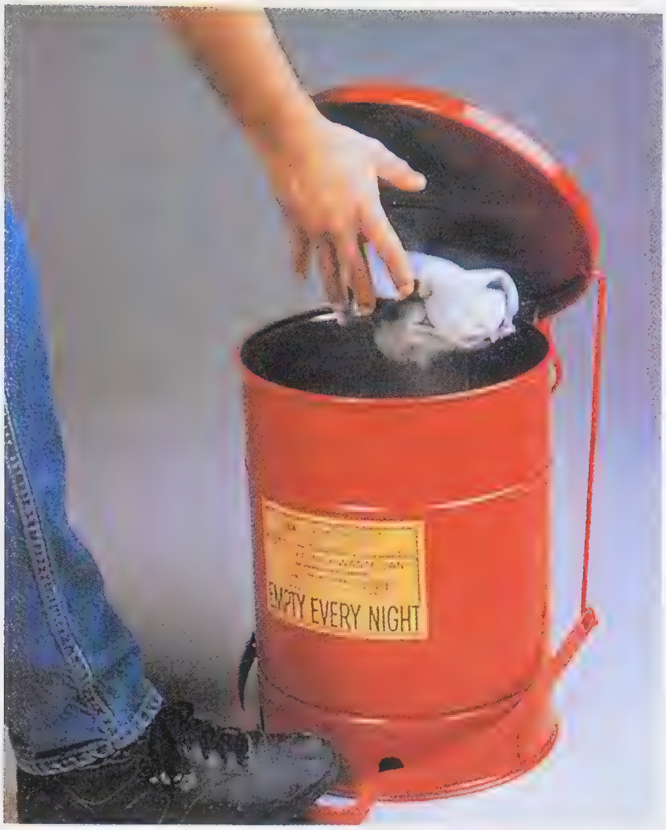


Figure 2-1. *Combustible waste, such as oily or solvent soaked rags, should be stored in an appropriate container. (Justrite Manufacturing Company)*

fire will stop. ***Fire extinguishers*** are designed to put out fires by removing either heat or oxygen.

Fires are classified by the type of material that is burning. Wood, paper, plastic, or cloth fires are classified as Type A fires. Type A fires can be extinguished by lowering the temperature of the combustibles. The Type A fire extinguisher is designed for use on Type A fires and uses water to lower the temperature of the combustibles.

Burning liquids, such as paint, thinner, and gasoline, are considered Type B fires. This type of fire should be smothered to remove the oxygen. Use a Type B fire extinguisher on burning liquids. Some Type B extinguishers use foam. The foam floats on the surface of the burning liquid, cutting off the oxygen and smothering the fire. Other Type B fire extinguishers use carbon dioxide to put out fires. The carbon dioxide sprayed from the extinguisher displaces the oxygen around the burning liquid, smothering the fire.

WARNING

Never use water or a Type A fire extinguisher in an attempt to put out a liquid fire. Spraying a Type B fire with water will cause the flames to spread.

Type C fires involve electrical equipment, such as motors, wiring, or switches. Before trying to extinguish this type of fire, shut off the electrical power if possible. A Type C fire extinguisher will apply a blast of nonconductive powder to smother the electrical fire. Type C fire extinguishers are often called dry chemical extinguishers.

Type D fires involve burning metals, such as magnesium. To extinguish this type of fire, a Type D, dry-chemical fire extinguisher should be used. A chart illustrating various fire classifications and fire extinguisher types is shown in **Figure 2-2**.

A multipurpose fire extinguisher can be used for a variety of fires. The most common type of multipurpose extinguisher is an A, B, C dry-chemical fire extinguisher.

Know where the fire extinguishers are located in the shop. Take time to learn how to use the extinguishers before you need them. If you wait until a fire breaks out, it may be too late.

Explosion Hazards

Volatile liquids are the primary explosion hazard encountered by the collision repair technician. A ***volatile liquid*** is a liquid that evaporates readily when exposed to the air. The vapors created as volatile liquids evaporate are extremely flammable. These vapors can build up during storage to a concentration that is great enough to explode if exposed to a spark or flame. Volatile liquids include gasoline, lacquer thinner, enamel reducer, and many carbon-based solvents. Carbon-based solvents can release ***volatile organic compounds***, or VOCs. In addition to being explosion hazards, VOCs can cause air pollution (photochemical smog) and health problems for technicians.

When a volatile liquid is ***atomized***, or broken up into small droplets, the mist created presents an even greater explosion hazard than the liquid itself. Atomization produces a much greater concentration of vapors in a shorter period of time than evaporation. Liquid paint is atomized in a spray gun. Atomization of the liquid allows a smooth coat of paint to be applied to a surface.

Paint should be sprayed only in approved locations, such as in a spray booth or paint prep station. See **Figure 2-3**. To prevent the buildup of vapors or mists, the mixing area, storage area, and spray area must be properly ventilated. A ventilation system moves air through the shop, replacing contaminated air with fresh air. The replacement of all the contaminated air in a confined area, such as a paint mixing room or paint storage room, is called an ***air change***. Fire protection codes will specify the number of air changes per hour needed to prevent the buildup of a hazardous concentration of vapor.

Fire Extinguishers and Fire Classifications

Fires
Class A Fires Ordinary Combustibles (Materials such as wood, paper, textiles.) *Requires...* *cooling-quenching.* A
Class B Fires Flammable Liquids (Liquids such as grease, gasoline, oils, and paints.) *Requires...blanketing or smothering.* B
Class C Fires Electrical Equipment (Motors, switches, etc.) *Requires...* *a nonconducting agent.* C
Class D Fires Combustible Metals (Flammable metals such as magnesium and lithium.) *Requires...blanketing or smothering.* D

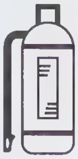
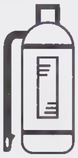
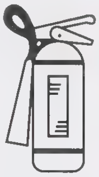
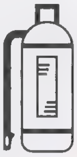
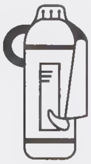
Type	Use	Operation
Soda-acid Bicarbonate of soda solution and sulfuric acid 	Okay for use on A Not for use on B C D	Direct stream at base of flame.
Pressurized Water Water under pressure 	Okay for use on A Not for use on B C D	Direct stream at base of flame.
Carbon Dioxide (CO_2) Carbon dioxide (CO_2) gas under pressure 	Okay for use on B C Not for use on A D	Direct discharge as close to fire as possible, first at edge of flames and gradually forward and upward.
Foam Solution of aluminum sulfate and bicarbonate of soda 	Okay for use on A B Not for use on C D	Direct stream into the burning material or liquid. Allow foam to fall lightly on fire.
Dry Chemical 	Multi-purpose type Okay for A B C Not okay for D Ordinary BC type Okay for B C Not okay for A D	Direct stream at base of flames. Use rapid left-to-right motion toward flames.
Dry Chemical Granular-type material	Okay for use on D Not for use on A B C	Smother flames by scooping granular material from bucket onto burning metal.

Figure 2-2. *This chart illustrates the various fire classifications and the fire extinguisher types. An extinguisher designed for electrical and chemical fires should be used in the collision repair shop.*

Figure 2-3. *Paint should be sprayed in approved spray booths or other approved locations.*

In a spray booth, the velocity of the air moving through the booth, measured in lineal feet per minute (FPM), prevents the buildup of a hazardous concentration of mist. The ventilation system in the spray booth removes the mist, replacing the contaminated air with fresh, filtered air. In one type of spray booth, a minimum air velocity of 100 FPM is required for safe operation.

The spray booth exhaust fan pulls the mist-laden air from the booth. This air is filtered and then discharged outside the building. Most spray booths are also equipped with an intake fan to push fresh air into the booth. This fresh air, taken from outside the building, is called ***make up air***. In cold climates, the make up air is often heated before it enters the booth. Some paint prep stations have curtains instead of walls like a spray booth. They also have an exhaust fan and, in some cases, an intake fan.

A spark caused by static electricity can create an explosion as lacquer thinner is transferred from a metal drum to a smaller metal container. To prevent an explosion, connect the drum to a good ground. The smaller metal container should be a safety can with a self-closing lid, and it should be connected to the drum with a ground wire. In this way, both the drum and the safety can are grounded. The wire connecting the drum to ground should remain in place the entire time the drum is stored.

Chemical and Biological Hazards

The primary chemical hazards in a collision repair shop are found in the paint products. Solvents, such as enamel reducer and lacquer thinner, are added to paint to dilute it to a sprayable consistency. The process of adding solvents to paint is called ***reduction***. These solvents evaporate, releasing VOCs into the air during the spraying process and as the paint dries. VOCs in the atmosphere cause a type of air pollution known as photochemical smog.

To help reduce air pollution, the United States government has set limits on the amount of VOCs, measured in pounds per gallon, that can be present in various types of paints. High-solids paints contain less solvent and more solids than non-high-solids paints. The use of high-solids paints has reduced the quantity of VOCs entering the atmosphere.

Another way to reduce the VOCs entering the atmosphere is to use high-volume low-pressure (HVLP) spray guns. ***Transfer efficiency*** is a measure of the amount of paint that coats a surface compared to the amount of paint that is actually sprayed. The paint transfer efficiency of a standard spray gun ranges from 20%–50%, depending on the spray technique. The HVLP spray gun has a transfer efficiency that ranges from 60%–90%. A more efficient transfer of paint means that fewer VOCs will enter the atmosphere. Another advantage of HVLP guns is that significantly less paint is required to refinish the vehicle, reducing costs.

Some chemicals in liquid paint are toxic. Toxic substances that are poured on the ground may seep down into the groundwater. Groundwater contamination can pose a health hazard to anyone drinking the water.

Paint hardeners, or catalysts, contain a family of chemicals called isocyanates. These chemicals help strengthen the paint film. Unfortunately, isocyanates also pose a health hazard. Inhalation of isocyanates leads to sensitization. ***Sensitization*** means that whenever the individual breathes even a small amount of isocyanate-laden air, an asthmalike acute reaction will occur. Sensitization may take days or years, but it will eventually happen to anyone who breathes isocyanates. Isocyanates can also be absorbed through the skin and mucous membranes, such as the eyes, mouth, and nose.

Most sensitized individuals cannot work in a collision repair shop. The risk of exposure is too great. After sensitization, each subsequent exposure will bring on more severe symptoms—wheezing, coughing, and shortness of breath.

Other toxic chemicals in a collision repair shop include engine oil and antifreeze. All these toxic chemicals require proper disposal.

Another chemical hazard encountered in the shop is carbon monoxide. An internal combustion engine produces carbon monoxide (CO) as it runs. Carbon monoxide is a colorless, odorless gas that is extremely toxic. The CO concentration will gradually increase if a vehicle is allowed to run in a confined space with no ventilation. Anyone spending time in the confined space as the carbon monoxide concentration increases can die from asphyxiation.

Biological hazards encountered in the collision repair shop include blood-borne pathogens and other infectious materials. Blood-borne pathogens are disease causing microorganisms found in human blood, including the hepatitis B virus (HBV) and the human immunodeficiency virus (HIV). Collision repair technicians may come in contact with blood-borne pathogens when removing soiled materials from a wrecked vehicle or when performing first aid on an injured co-worker.

Electrical Hazards

Electrical current traveling through the body causes electric shock. A severe electric shock causes electrocution. Damaged or improperly used electric tools can lead to an electric shock if they allow electrical current to reach the body. Bare electrical wires are also a shock hazard. Inspect electrical cords and tools to make sure they are in good condition. The extension cord shown in **Figure 2-4** has been damaged and must not be used until it is repaired properly.

Keep electrical wires and extension cords off wet surfaces. Do not use electric tools or handle live extension cords while standing on wet floors. Never operate several electrical devices from a single extension cord. This may overload the extension cord, causing it to overheat and melt from excessive current flow. Never operate high-current devices, such as air compressors or welders, through extension cords. Instead, plug these devises directly into the proper wall outlet.

Make sure electric tools are properly grounded before use. If the tool is equipped with a grounded plug, make sure the third prong is intact. See **Figure 2-5**.

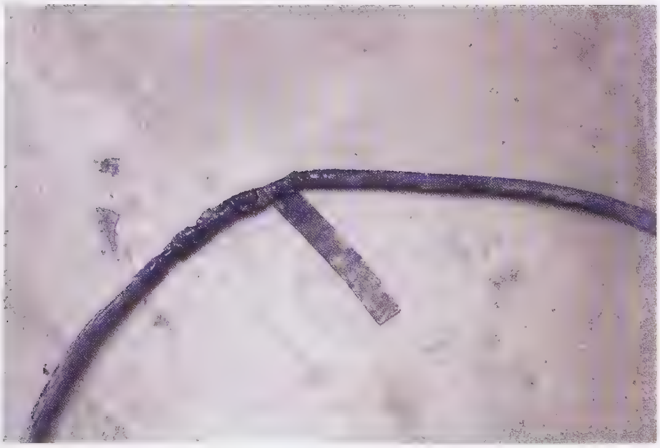


Figure 2-4. *Damaged electrical cords should be repaired or replaced before they are used. The cord shown here was damaged and poorly repaired. It should be replaced.*

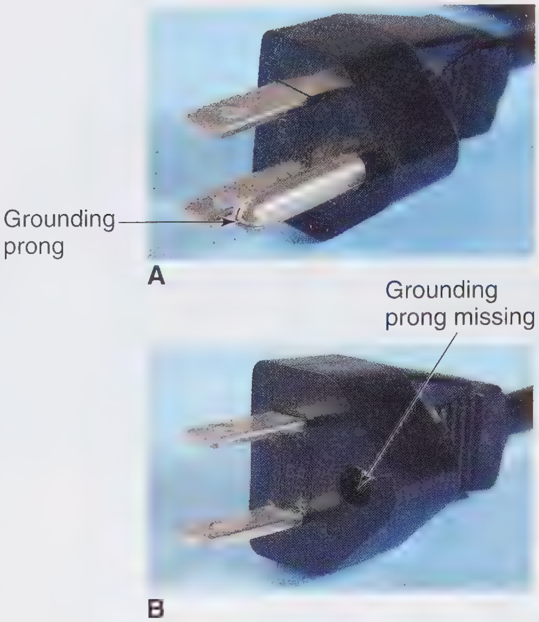


Figure 2-5. *Electric tools and equipment must be properly grounded. A—A plug with the grounding prong intact. B—The grounding prong has been removed from this plug. To prevent an electrocution hazard, this plug should be replaced before the electrical device is used.*

An automotive battery releases hydrogen gas, which is an explosion hazard. A spark or flame could ignite this gas. If, for example, you accidentally short the positive terminal of the battery to ground, you will create a spark that could ignite the hydrogen gas.

Hybrid vehicles also pose electrical hazards. A hybrid vehicle has a gasoline-powered engine and a battery-powered electric motor/generator. A portion of the hybrid vehicle's electrical system operates on extremely high voltage. This is where the shock hazard is lurking. Removing or switching off the high-voltage disconnect will prevent current flow through the high voltage system. See **Figure 2-6**. The technician must be specially trained before working on hybrid vehicles. To avoid electrocution, the technician should wear approved rubber insulated electrical gloves (insulation value of 1000 V or more) when working on or near live high-voltage circuits in a hybrid vehicle.

Noise Hazards

Collision repair shops can be noisy places to work. A collision repair shop will have at least a moderate level of noise at all times. When tools such as air chisels or impact wrenches are used, the noise can be deafening. The pounding sound waves produced by loud noises can damage eardrums. Damaged eardrums will gradually but permanently lose the ability to distinguish sounds.

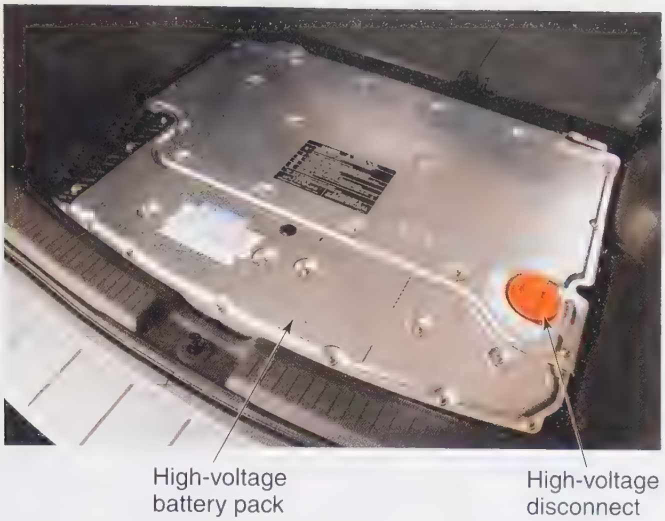


Figure 2-6. *To prevent shock or electrocution when working on a hybrid vehicle, the high-voltage disconnect must be removed or turned to the off position. On this particular hybrid vehicle, the disconnect is located on the high-voltage battery pack. It must be unlocked, removed, and reinstalled in the "service" position to disconnect power to other parts of the hybrid vehicle. (Ford)*

Injury Hazards

Cuts, burns, and sprains are common collision repair shop injuries. Collision repair technicians work with sharp metal, such as the edges of steel replacement parts and sheet metal torn during impact. The sharp edges can cut a technician. A deep cut may require stitches to close the wound. All cuts are subject to bacterial infection.

Burns can result from careless welding. The intense light produced during MIG welding can cause first-degree burns to unprotected skin and retina damage to unprotected eyes. Sparks and slag from welding can cause second-degree burns on unprotected skin.

Muscle sprains can be caused by slipping or falling on slippery surfaces. Oil and antifreeze spills can make the floor extremely slippery and should be cleaned up immediately. Pour absorbent on the spilled liquid. Once the absorbent has soaked up the liquid, sweep up the absorbent and dispose of it in an appropriate container.

The technician can trip and fall over tools and parts on the shop floor. Keep tools in a toolbox rather than allowing them to be scattered about the work area. See **Figure 2-7**. Find a separate storage place for the damaged parts removed from each vehicle. Stack the parts neatly so they are out of the way. The damaged parts should be kept until the vehicle is returned to the customer.

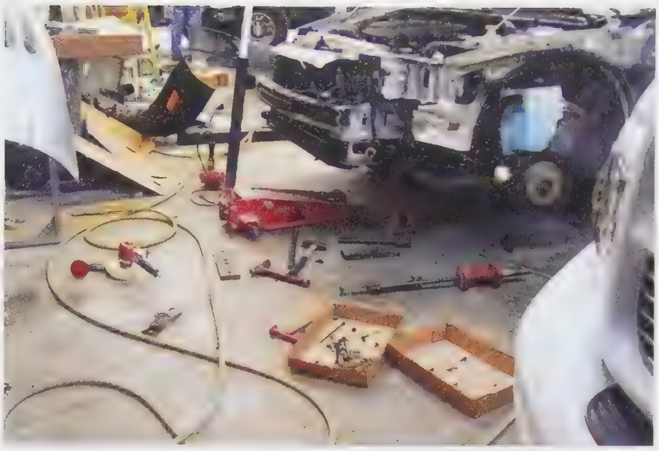


Figure 2-7. *This work area is a safety hazard. The shop should be kept clean and organized to prevent falls and other injuries.*

Grinding and cutting generate small pieces of steel, aluminum, plastic, or other materials that can be thrown toward your skin and eyes. Unprotected eyes are particularly vulnerable to injury during grinding and cutting operations. Even a very small piece of debris that gets into your eye can cause irritation, infection, and even loss of vision.

Collision technicians are often required to work under raised vehicles. Vehicles can be safely raised on a lift or they can be raised with a floor jack and placed on jack stands. Never crawl under a vehicle that is supported only by a floor jack or any other type of jack. The jack could inadvertently release, allowing the vehicle to fall on you.

Improper lifting or trying to lift something that is too heavy may cause back muscle strain, disc damage, or inflammation. Many replacement parts, such as bumper assemblies, doors, and hoods, are heavy. These parts must be lifted and held in place during installation. Improper lifting can lead to injury.

Figure 2-8 shows the proper way to lift a heavy object. Do not bend your back. Instead, bend your knees and use your legs to lift the object. There is a limit to the amount of weight a person can lift. Know your limitations. Whenever possible, get help lifting heavy objects. A floor jack can be used to raise and position a bumper assembly. Special devices are available to raise, lower, and position doors. See **Figure 2-9**.

To prevent injury, never use your hands, feet, knees, or elbows to strike an object when attempting to move or align a part. Instead, use a proper tool. For example, you could use your elbow to open a stuck tailgate. However, hitting the tailgate with a rubber hammer will eliminate the chance of injury.

Repetitive stress injury is the inflammation of muscles or tendons caused by performing the same action again and again. Swelling of the inflamed area may affect nerves, causing pain or numbness.

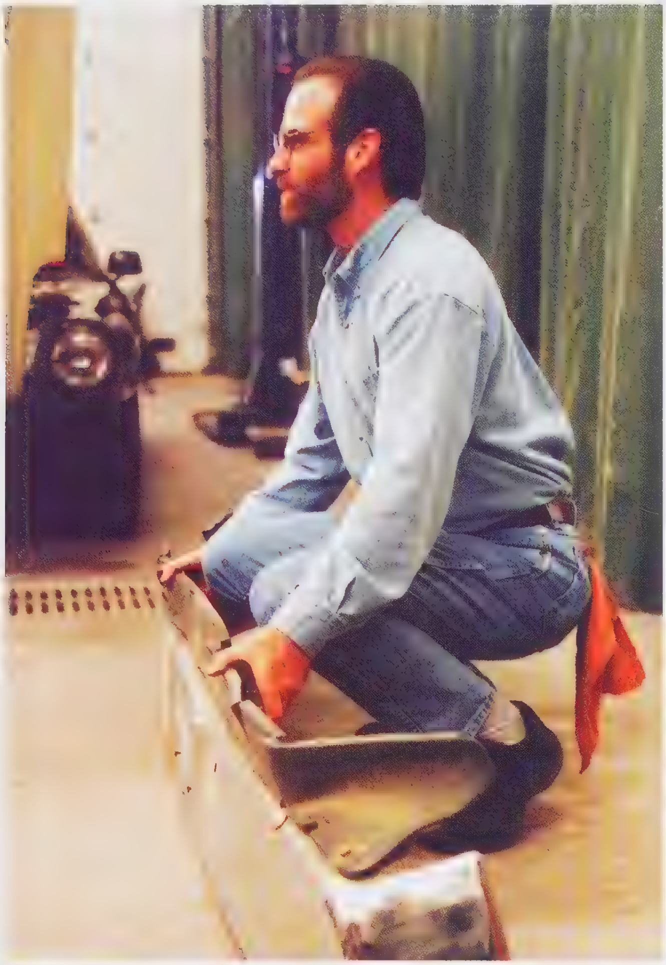


Figure 2-8. *When lifting heavy objects, keep your back straight and lift with your legs. This will help prevent back injury.*

A repetitive stress injury can also occur when a muscle or a group of muscles is contracted for an extended period of time. This contraction, or shortening, of the muscle pulls on the tendons the muscle is attached to, causing inflammation.

Vibration can also contribute to repetitive stress injury. In a collision repair shop, this vibration could come from hand block sanding for long periods or continuous use of an air chisel. Common types of repetitive stress injuries are carpal tunnel syndrome and tendonitis.

To avoid repetitive stress injury, do not perform a specific task for an extended period. When hand block sanding, change body position occasionally so the same muscles are not kept contracted for extended periods of time. Do not use an air chisel continuously. Take a break every 15 minutes or whenever you feel pain or numbness in your arms. Improve your posture when working at a computer and take time to stretch.

A vehicle's air bags can deploy with deadly force. Safety must be a primary concern when working on or near air bag system components. Disable the air bag system before servicing the steering wheel, dashboard, or other areas where the system parts are located. Always follow the directions in the service manual for the specific vehicle being serviced. When carrying an undeployed (live) air bag module, point the module away from your body. Set an undeployed air bag module face up. For more information on servicing air bag systems, refer to Chapter 23, *Restraint Systems*.

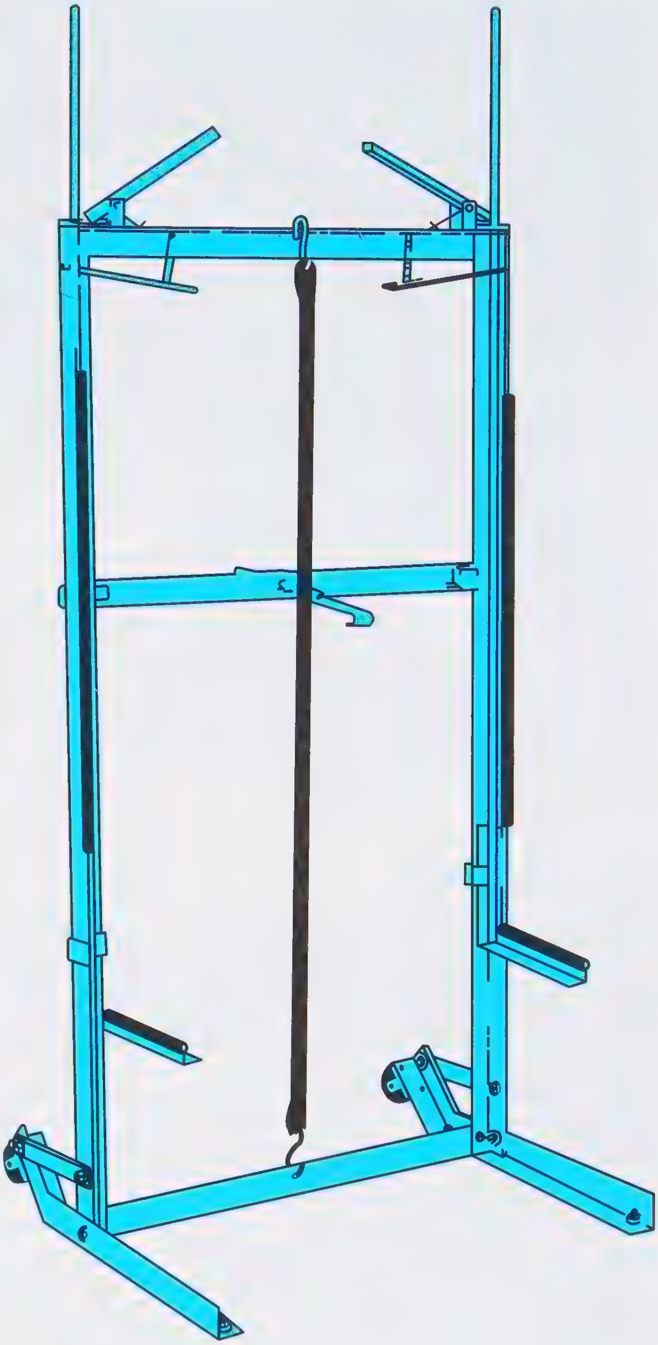


Figure 2-9. *This lift is used to elevate and position doors for ease of service. (Steck)*

Personal Protective Gear

This section describes the various types of personal safety equipment that should be used when working in the collision repair shop. The appropriate safety equipment for various collision repair tasks is summarized in **Figure 2-10**.

Eye Protection

Eyes are vulnerable to particles thrown through the air when grinding or cutting, liquids splashed when mixing paint, and intense light generated when welding. Eye protection must be a concern for every collision repair technician and shop visitor. See **Figure 2-11**.

Welding and Cutting	
• Welding helmet or goggles • Safety glasses • Welding gloves	• Welding cape • Long pants • High-top shoes • Welding respirator
Straightening	
• Safety glasses • Leather gloves	• Ear protection
Grinding and Cutting	
• Safety glasses • Face shield • Dust mask • Leather gloves	• Ear protection • Long pants/sleeves • High-top shoes
Sanding	
Dry sanding	Wet sanding
• Safety glasses • Dust mask • Work gloves • Ear protection	• Safety glasses • Cotton gloves
Painting	
Non-isocyanate paints	Isocyanate paints
• Safety glasses • Paint suit • Spray sock • Neoprene gloves • Cartridge respirator	• Safety glasses • Paint suit • Spray sock • Neoprene gloves • Supplied air respirator
Mechanical Repair	
• Safety glasses • Face shield	• Work gloves • Ear protection

Figure 2-10. *The safety equipment used for various collision repair tasks is summarized in this chart.*

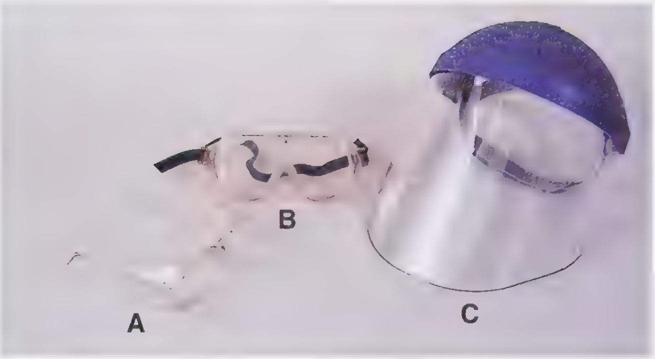


Figure 2-11. *Various types of eye protection are worn in the collision repair shop. A—Safety glasses. B—Safety goggles. C—Face shield.*

Safety glasses, Figure 2-11A, protect the eyes from most particles and liquids. The lenses used in safety glasses are rated according to their impact resistance. Both basic and high-impact lenses are available. Safety glasses may have small side shields for protection from side impacts.

Safety glasses should be worn so they fit tightly against the forehead. Even when properly worn, safety glasses cannot protect against all particles and liquids. These harmful substances may be able to get around the glasses.

Safety goggles, Figure 2-11B, fit tightly around the eyes. Goggles are not as comfortable as safety glasses, and they often fog up. However, goggles do provide superior eye protection against particles and liquids. A face shield, shown in Figure 2-11C, protects the entire face, not just the eyes. However, because the face shield does not fit tightly against the face, contaminants may be able to get around the shield. Therefore, safety glasses should be worn with a face shield.

Never rub or scratch your eyes with a contaminated glove or sleeve. This could deposit metal particles or liquids in your eyes, negating the safety effect of eye protection.

If you do get liquids or particles in your eyes, rinse the contaminants from your eyes at an eyewash station. Some eyewash stations provide a stream of fresh water to help rinse contaminants from your eyes. Other stations, such as the one shown in **Figure 2-12**, contain a bottle of sterile rinsing solution. Be sure you know how to use the eyewash station before you need it.

WARNING

If you get a metal particle in your eye, do not rub your eye. Rubbing will drive the metal deeper into your eyeball. The particle must be removed by a doctor.

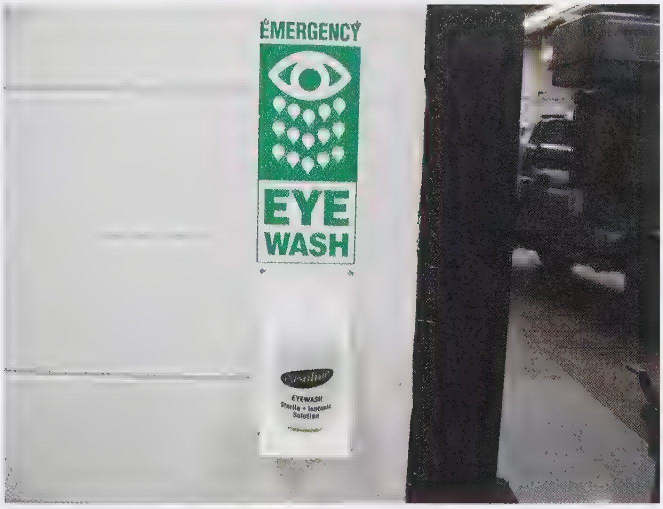


Figure 2-12. *This emergency eyewash station contains a sterile solution that is used to flush contaminants from your eyes. Eyewash stations should be located in prominent locations in the shop.*

In addition to the hazards from metal particles and liquids, intense light from welding can harm the eye. Eye damage may not be apparent during welding. In fact, the effect may be delayed a few hours. Eye damage can lead to a loss of vision. To protect the eyes from the light of an oxyacetylene torch, wear welding goggles or a tinted face shield. See **Figure 2-13**. Arc welding produces a more intense light than an oxyacetylene torch. Wear an arc-welding helmet when arc welding. An arc-welding helmet, **Figure 2-14**, has highly tinted lenses to protect eyes from arc-welding light.

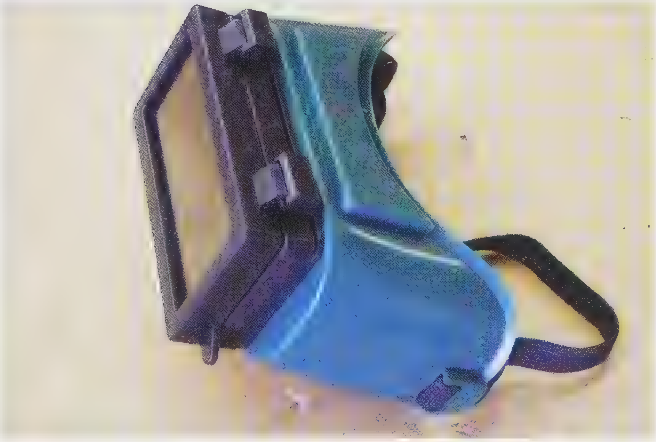


Figure 2-13. *Welding goggles will protect your eyes from the bright light produced by an oxyacetylene torch.*

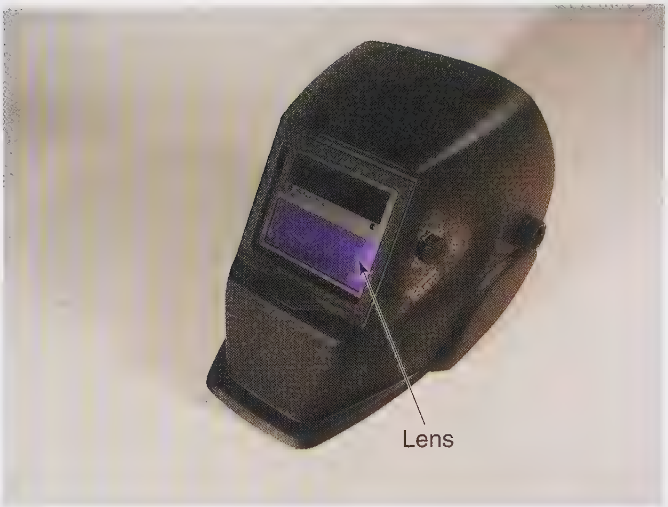


Figure 2-14. *An arc-welding helmet must be worn to protect your eyes and face during arc-welding procedures.*

Ear Protection

A busy collision repair shop will be noisy and even deafening at times. Constant exposure to loud noises will lead to progressive hearing loss. Earmuffs and earplugs, shown in **Figure 2-15**, will dampen the sound waves acting on your eardrums, preventing hearing loss. You will still be able to hear when wearing ear protection, but the loud noises will not harm your eardrums.

Respiratory Protection

Sanding body filler and paint produces harmful dust. Breathing sanding dust will gradually damage a

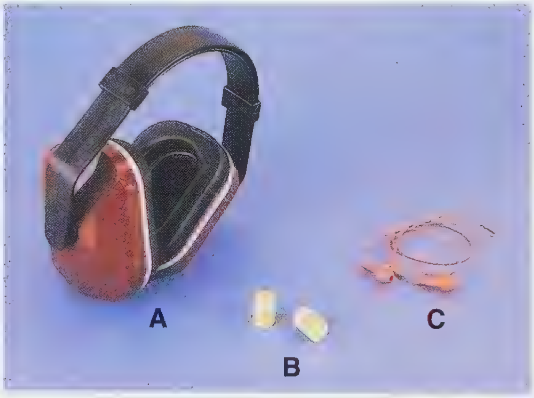


Figure 2-15. *Ear protection should be worn when working in noisy areas. A—Earmuffs. B and C—Earplugs.*

technician's lungs. A ***dust mask***, shown in **Figure 2-16**, must be worn when dry sanding. The dust mask will gradually become clogged with dust. Discard the mask when the outside of the mask looks dirty.

WARNING

A dust mask will not protect against the dangers associated with breathing certain mists or vapors.

A ***respirator*** is designed to protect the lungs from harmful vapors and mists. When spraying or mixing paints that do not contain isocyanates, a technician can wear a cartridge-type respirator. This type of respirator works only in well-ventilated areas. The ***cartridge-type respirator*** removes contaminants from the air the technician breathes. This type of respirator uses an activated carbon cartridge to absorb the harmful chemicals in paint vapor and mists. See **Figure 2-17**. The activated charcoal absorbs carbon-based (also called organic) chemicals in the breathing air. A prefilter on top of the activated carbon cartridge removes dust from the air.

Activated carbon cartridges must be replaced periodically. Useful service life depends on several variables, including the amount and type of contaminants in the air, the temperature and humidity in the work area, and the rate of airflow through the respirator. Refer to the manufacturer's literature for specific recommendations.

A respirator should be cleaned after each use, especially if it is shared among technicians. Begin by removing the cartridges and any pre-filters from the respirator. Then disassemble the respirator, wash it with an approved cleaner or disinfectant, and rinse it in clean running water. Some respirator manufacturers allow the inside of the respirator to be disinfected by wiping it with 70% isopropyl alcohol. After cleaning, dry the respirator with a clean cloth or allow it to air dry. Then inspect all parts for distortion, wear, and deterioration; and reassemble the respirator. Finally, test the respirator to make sure that it is working correctly.

Figure 2-16. *A dust mask should be worn during dry sanding operations.*

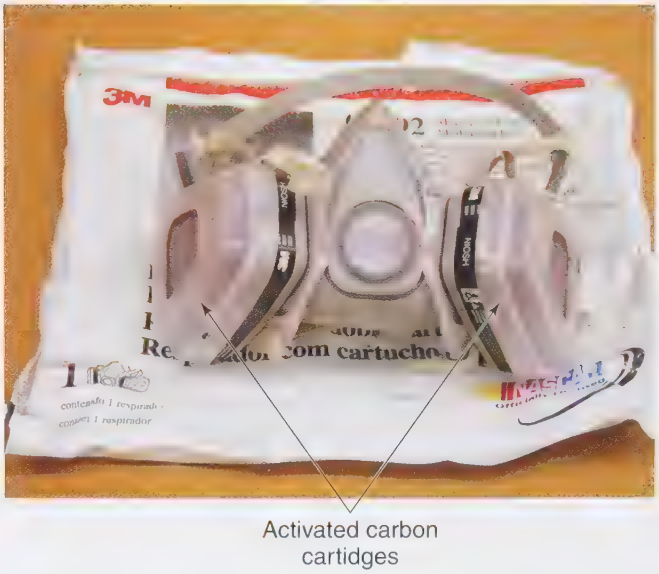


Figure 2-17. *A cartridge-type respirator is designed to absorb some types of harmful vapors and mists.*

The activated carbon cartridges absorb chemicals whenever they are exposed to the air. Storing the respirator in an airtight bag prolongs the life of the cartridge. The stored respirator should be positioned so that the face contact portion does not distort. If the face contact area is distorted, it will not seal properly.

A cartridge respirator cannot remove isocyanates from the air and should never be used when spraying isocyanate-containing paint. Therefore, a supplied-air respirator is required when spraying isocyanate-containing paint. A ***supplied-air respirator*** provides the technician with clean, safe air from outside the spray area.

There are two types of supplied-air respirators. The first type uses filtered air from the compressed air line in the spray booth. To be used for both spraying and breathing, this air must pass through a series of filters that removes contaminants. The compressor's air intake must be located in a fresh air area, away from spraying operations and vehicle exhaust. The air compressor used in this type of system must be carefully maintained. If the compressor overheats, carbon monoxide, a lethal gas, may be added to the compressed air.

One brand of supplied-air respirator uses this series of three filters: first, a water and 5-micron particle filter; then, an oil and 0.01-micron particle filter; and finally, an oil vapor, hydrocarbon, and odor filter. A special air line conducts the filtered, breathable compressed air to a hood or mask worn by the technician. A hood covers the entire head, while a mask covers only the nose and mouth. Compressed air for the spray gun passes through the three filters and is then routed through a desiccant tank, which removes water vapor.

The second type of supplied-air respirator uses an oil-less air compressor to pump treated breathing air to a hood or mask. A separate compressor and line are used to supply the spray gun. The oil-less air compressor is positioned outside the spray area, so it can pull in clean air. A supplied-air respirator is shown in **Figure 2-18**.

Skin Protection

Cutting and grinding metal or working around sharp edges can lead to cuts and abrasions. Protect your skin by wearing leather gloves when grinding, cutting, or handling sharp materials. Leather work gloves are shown in **Figure 2-19**.

Harmful substances in paints and solvents can be absorbed through the skin. Neoprene gloves, shown in **Figure 2-20**, protect the skin from harmful chemicals. Wear neoprene gloves when mixing or spraying paint, cleaning a spray gun, and handling solvents. When painting, be sure to wear a paint suit and a spray sock. The paint suit is a one-piece garment that keeps the paint off your body. A spray sock is a hood that protects your head and neck.

NOTE

The protective clothing and equipment worn to help protect against the sparks and intense light encountered when welding are covered later in this chapter.

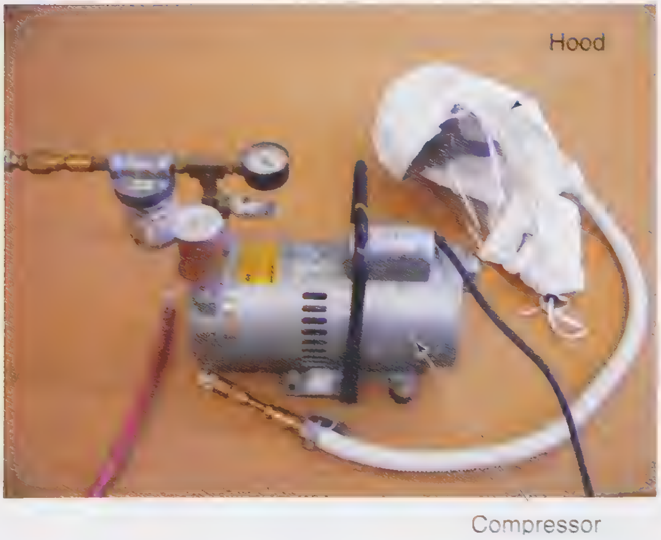


Figure 2-18. *A supplied-air respirator must be worn when working with paints that contain isocyanates.*

Figure 2-19. *A good pair of leather gloves will protect your hands from cuts and abrasions.*

Figure 2-20. *Neoprene gloves should be used with working with harmful chemicals.*

Steel-toed shoes protect feet from injury caused by falling objects. Similarly, a hard hat protects your head from falling objects. Also, when you work under a vehicle that has been raised on a lift, the hard hat will prevent you from hurting your head if you bump into the catalytic converter or other obstruction under the vehicle.

Safe Work Practices

The following section describes safety practices associated with the specific tasks performed in the collision repair shop. Following these practices will reduce the chances of accidents by eliminating or minimizing many of the hazards encountered in the shop. Always keep safety in mind when working in the collision repair shop.

Welding and Cutting Safety

MIG welding, resistance spot welding, plasma cutting, and flame cutting are the most common welding and cutting procedures performed in the collision repair shop. Welding and cutting produce sparks. If these sparks are allowed to contact an unprotected vehicle, they can start a fire or pit paint and glass. If the sparks land on the technician, they can cause serious burns. Welding galvanized metal causes toxic zinc gas to be released.

WARNING

MIG welding produces extremely bright light. This light is so intense that it can permanently damage an unprotected eye and cause skin burns.

When performing welding or cutting operations, the technician must be protected with the appropriate safety equipment. See **Figure 2-21**. Typical protective clothing and equipment that should be used when welding and cutting include:

- Welding helmet—A #10 shade will block the intense MIG welding light.
- Welding goggles—Goggles with a tinted lens will protect your eyes from the bright light produced by an oxyacetylene torch.
- Safety glasses—Safety glasses with side shields should be worn whenever a welding helmet or welding goggles are not required.
- Welding gloves—Leather gloves will keep the sparks from burning the technician's hands and will prevent sunburn from the welding arc.
- Welding cape—A cape keeps sparks off the skin and prevents sunburn from the welding arc.
- Long pants—Long pants keep sparks off the skin and prevent sunburn from the welding arc.
- High-top shoes—Sparks can land in low-cut shoes, causing burns. High-top shoes prevent this from happening. Also, always wear leather shoes or boots when welding. Canvas shoes will not provide adequate protection.
- Welding respirator—A dedicated welding respirator protects the technician from harmful gases produced when welding. See **Figure 2-22**.
- Fan—A fan will prevent the buildup of zinc gas when welding galvanized steel.

The vehicle being repaired should also be protected during the welding or cutting process. Take the necessary steps to protect the glass, paint, and upholstery. Drape a welding blanket over the vehicle to protect the area around the weld. See **Figure 2-23**.

When using an electric welding or cutting process, disconnect the vehicle's negative battery cable. Electrical current passing through the vehicle's body can also

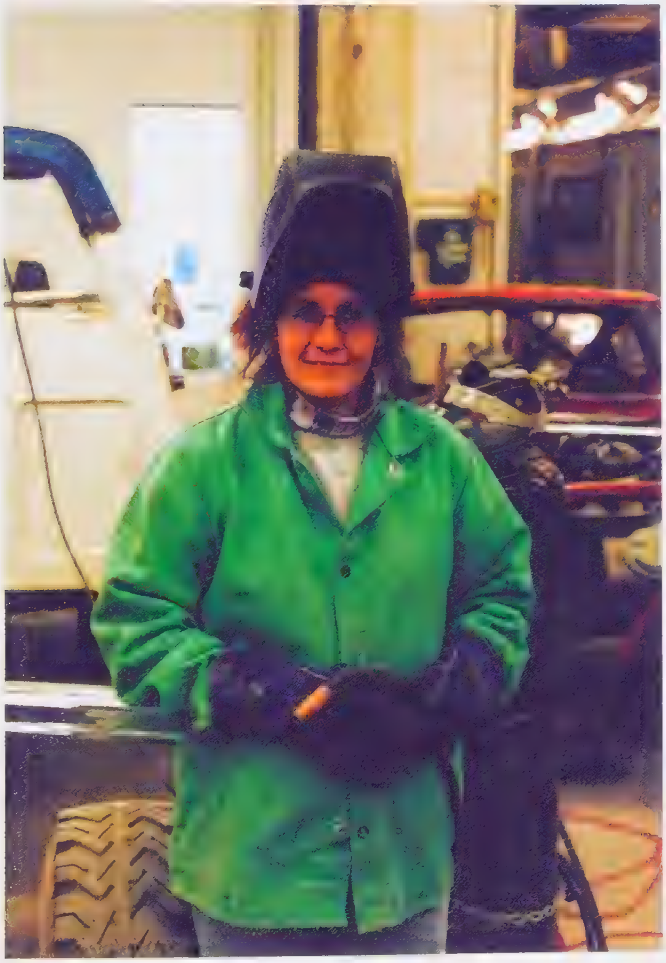


Figure 2-21. *This technician is wearing MIG welding safety equipment, including a welding jacket, welding gloves, and a welding helmet.*

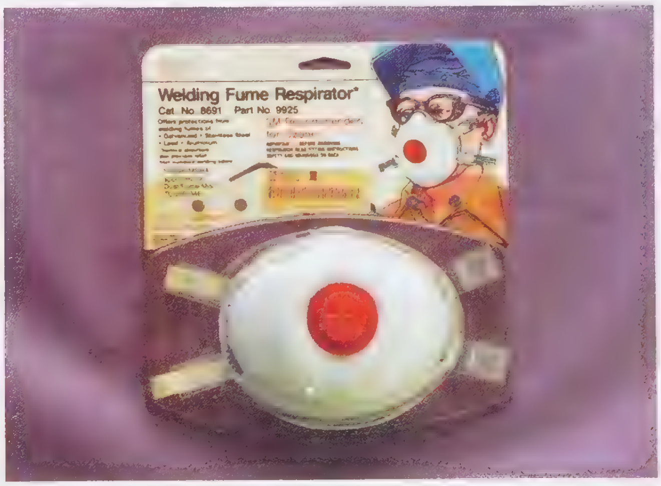


Figure 2-22. *A welding respirator will protect the technician from harmful welding fumes.*

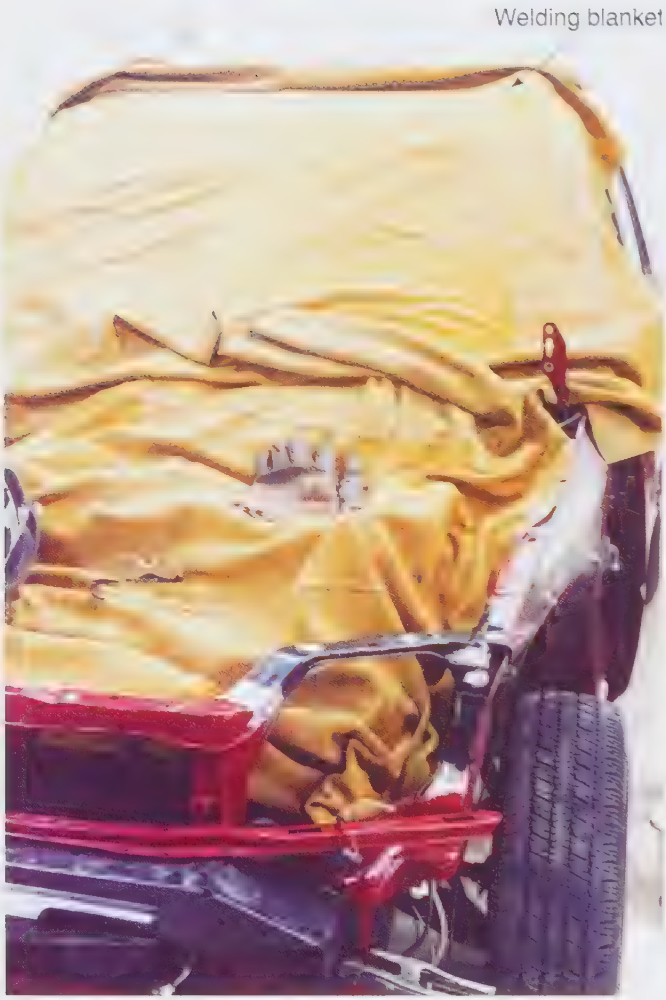


Figure 2-23. *A vehicle's paint and glass must be protected during welding or cutting processes. As shown here, a welding blanket can be used to cover these surfaces.*

travel through the vehicle's electrical system. Disconnecting the negative battery cable will prevent this from occurring. Also, disconnect and remove the vehicle's computers. The current generated when welding may damage computers located in the weld area. After removing a computer, protect it by placing it in a static-free bag and storing it in a clean, dry area.

Look inside the panels to be welded for sound-deadening bags, insulation, or undercoating. All these materials are flammable and must be removed before you begin welding or cutting. Never heat an object that contains gas or liquid. Heating a gas- or liquid-filled container, such as a bumper isolator, can cause an explosion. Do not weld or cut near gas lines or rubber isolators. Remove these components before applying heat.

Remove combustibles, such as masking paper, cardboard boxes, or thinner cans, from the work area before welding or cutting. Set up a weld screen around the area to keep sparks from traveling.

If applicable, make sure gas cylinders are chained or otherwise secured in place against a wall or on a cart. See **Figure 2-24**. If a cylinder is knocked over, the valve could be damaged. If the valve breaks, the gas inside the tank will be released. An oxygen tank is under about 2000 psi (13,800 kPa) of pressure. An acetylene tank is under about 250 psi (1724 kPa) of pressure. With either tank, the escaping gas could cause the cylinder to shoot across the shop with deadly force.

Stop all welding and cutting at least one hour before quitting time. If a weld is made just before quitting time and all workers leave the shop, combustibles inside or near the vehicle may be smoldering. After several minutes, they may burst into flames. The fire, which could have been easily handled if the technicians were in the shop, could be disastrous.

After welding, always be on the lookout for smoke. Smoke is an indication that something is smoldering. Use compressed air from a blowgun or water from a hose to put out the smoldering material. Many technicians keep an air hose and blowgun beside them when they are welding so they will be ready if a fire starts.

Straightening Equipment Safety

Tension is used to straighten damaged frames and sheet metal components. A straightening machine is a piece of tension-repair equipment that is capable of producing ten tons of force. If released all at once, this force can cause serious injury or even death.

A tension setup consists of a hookup, which is attached to the vehicle, a chain, and a pull source. See **Figure 2-25**. The chain is connected between the pull

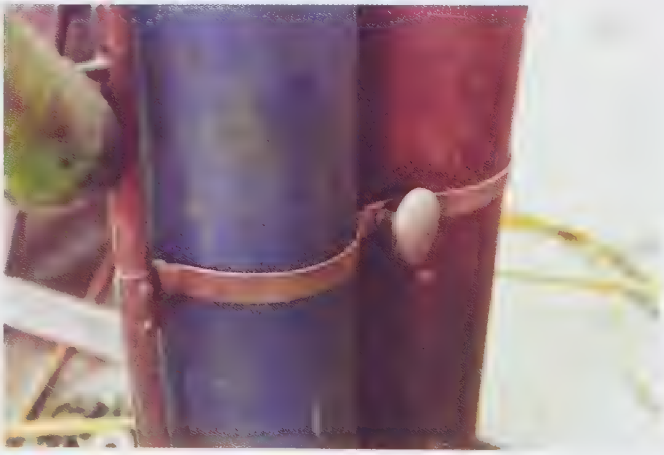


Figure 2-24. *Welding tanks must be fastened securely to the cart to prevent them from falling or being knocked over.*

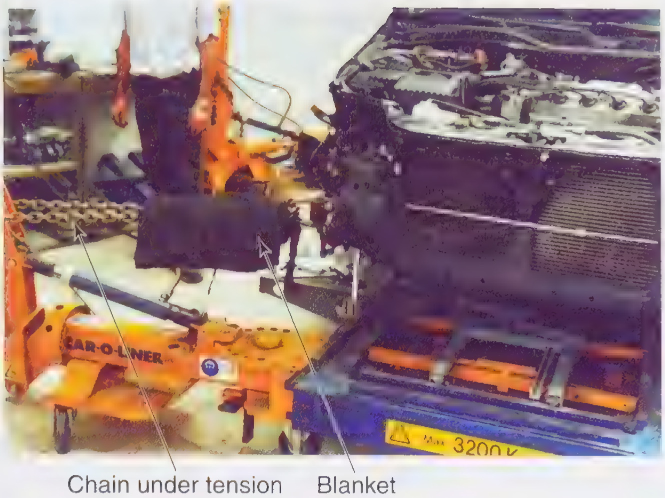


Figure 2-25. *Structural repairs are made using extreme tension. The chain is covered with a blanket so that if the hookup breaks loose, the chain will drop to the floor rather than fly through the air.*

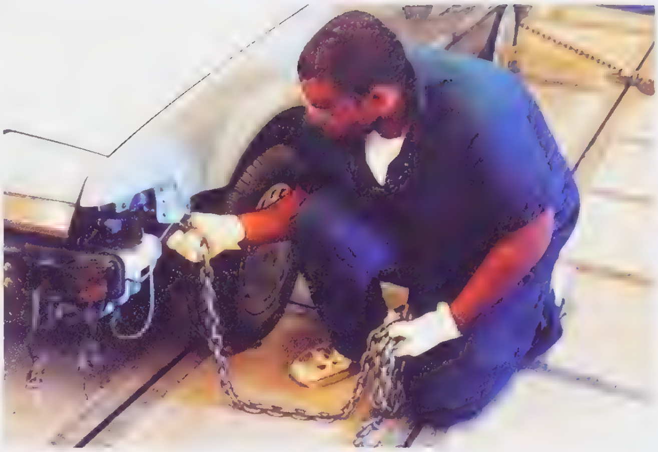


Figure 2-26. *This technician is wearing appropriate protective gear while hooking up straightening equipment.*

source and the damaged vehicle. The chain applies tension to pull out the damage. The hookup connects the chain to the damaged portion of the vehicle. The hookup can be made with clamps, welds, frame wraps, or hooks. Any of these hookups can fail while the pull is being made. If the hookup fails, the chain may fly back toward the source of the pull. The chain could hit anything or anyone in a direct line between the hookup and the pull source, causing damage or serious injury. Always alert everyone in the vicinity of the pull before tension is applied. Make sure everyone stands clear during the pulling process.

WORKING SMART

Place a heavy tarp or blanket over the chain before applying tension. This will help prevent the chain from flying back if it breaks under tension.

Never stand beside or straddle a chain that is under tension. The hookup may fail without warning. A proper hookup, which will be explained in later chapters, and a good chain will minimize the risk of a release. During the pulling process, watch for movement in the vehicle as tension is applied. If the frame, the hookup, the vehicle, or the chain does not move, stop pulling immediately. If you do not stop the pull, the extreme tension generated may cause something to break. Determine why the pull is not moving the damage and reposition the pull as necessary.

Always wear safety glasses and leather gloves when using straightening equipment. See **Figure 2-26**. Add ear protection if there will be a lot of hammering on the vehicle. Tension repairs require the use of many tools. Return tools to their proper storage locations when you are done using them. Tools left on the floor or on the bed of the straightening machine may cause a technician to trip and fall.

Grinding and Cutting Safety

Specific safety procedures should be followed when grinding and cutting. Both grinding and cutting produce heat, noise, and sparks. Grinding also creates dust. Cutting is done with a cut-off wheel or an air chisel, while grinding is done with a grinder.

Remove combustible materials from the work area before grinding or cutting. Sparks from cutting or grinding operations can cause pits in the paint, glass, or upholstery. Protect these areas with a welding blanket or a piece of cardboard. Also, cardboard and duct tape can be used to prevent the grinder from accidentally hitting parts adjacent to the work surface. To prevent damage and injury, know what is behind a panel before beginning any cutting operation. Grinding and cutting equipment can cut flesh as well as steel, so be careful.

The protective equipment that should be worn when grinding or cutting includes:

- Safety glasses—These will keep metal shavings out of the eyes.
- Face Shield—The face shield will protect your face from sparks and metal particles.
- Dust mask—If dust is produced during the process, a dust mask should be worn to protect the respiratory system.

- Leather gloves—Slipping while grinding or cutting can force the tool against the technician's hand. Gloves will keep the grinding disk or cut-off wheel from biting into the skin.
- Ear protection—Continued exposure to loud noises produced when grinding can cause gradual hearing loss. Ear protection will guard the eardrums from the shock of loud noise. See **Figure 2-27**.
- Long-sleeve shirts/long pants/high-top shoes—Sparks generated by grinding and cutting can cause burns on unprotected skin. Long-sleeve shirts, long pants, and high-top shoes will minimize the chance of burns.

Sanding Safety

Dry sanding, which is done to level body filler and remove paint, produces dust. Inhaled dust particles are a health hazard. A dust mask will protect a technician from dust particles. Dry sanding can be done by hand or with an air-powered sander. The amount of dust produced by power sanding can be reduced if a vacuum system is used. The vacuum system pulls air and sanding dust away from the sanding area.

Wear safety glasses to protect your eyes from dust particles. Power sanding can be loud, so appropriate ear protection should be worn. Rough sandpaper can injure the skin. Wear leather gloves if your hands directly contact the sandpaper. See **Figure 2-28**.

When sanding, cover adjacent vehicle surfaces to prevent damage. Close the windows and doors to keep the dust out of the vehicle's interior.

Wet sanding can be done by hand or with an air-powered sander. Wet sanding does not produce dust like dry sanding. Water, which is used as a lubricant, tends to wash away sanding residue. Nevertheless, wet sanding can be hazardous. Water from the wet sanding operation ends up on the floor. This causes the floor to be slick. Additionally, the wet floors pose a shock hazard. Never run electric cords over a wet floor.

Hand wet sanding with coarse sandpaper, such as 220-grit sandpaper, can wear away the skin on the fingertips. Wear gloves to protect the fingers when wet sanding by hand.

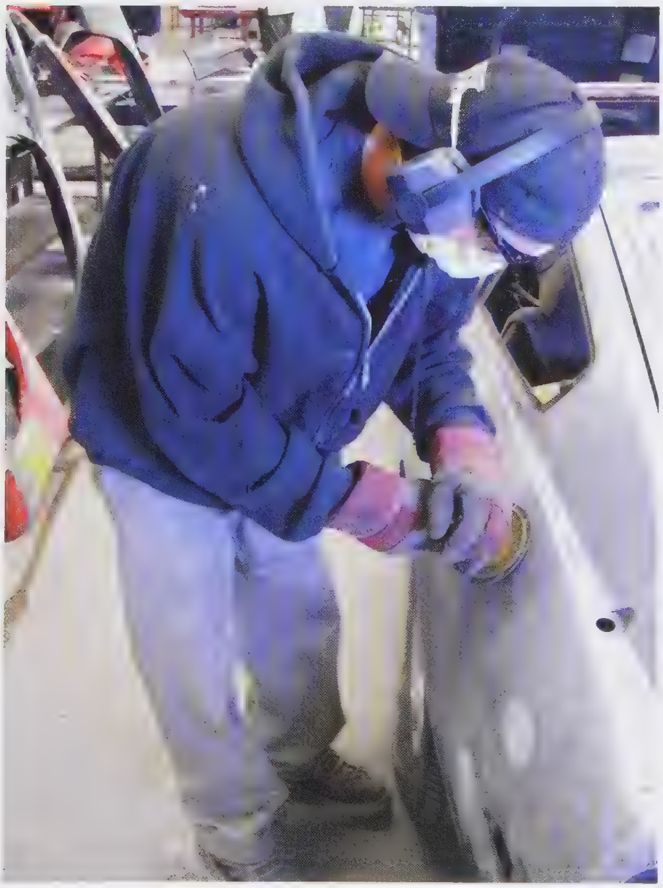


Figure 2-27. *Grinding requires gloves, safety glasses, a dust mask, ear protection, and long sleeves.*

Painting Safety

Painting exposes the technician to several hazards. Even paints that do not contain isocyantes are hazardous. With proper protection, a technician can enjoy a long and productive career in painting. Without adequate protection, the technician will eventually suffer health problems.

Protective gear that should be worn when working with non-isocyanate paint—paint without a hardener or

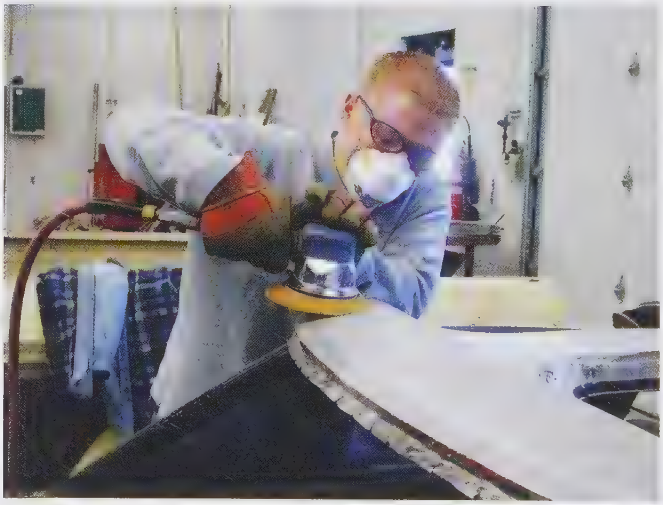


Figure 2-28. *This technician is wearing dry sanding safety equipment, including safety glasses, a dust mask, and gloves.*

catalyst— is shown in **Figure 2-29**. This gear includes the following:

- Paint suit—This garment keeps the mist off of the painter's skin.
- Spray sock—This hood keeps the mist off of the painter's hair and neck.
- Neoprene gloves—These gloves are impervious to solvents. They protect the painter's skin from exposure to the chemical in the paint.
- Respirator— A cartridge-type respirator will protect the technician from the vapors and mists generated by non-isocyanate paints.

Paint containing isocyanates—basecoat, single stage surfacer, or clearcoat—is potentially more hazardous than non-isocyanate paint. While both types of paint can cause long-term organ damage, isocyanate paint can also cause an acute reaction.

As previously mentioned, an unprotected technician who is exposed to isocyanates may have a reaction that occurs immediately after or within hours of exposure. The symptoms of isocyanate exposure include shortness of breath, wheezing, coughing, and nausea. Prolonged exposure will lead to more serious symptoms. A painter who becomes sensitized must generally find another occupation. Even small amounts of isocyanates can cause a severe reaction in a sensitized person.

The painting apparel for isocyanate paint is the same as that for non-isocyanate paint. However, a supplied-air respirator must be worn when working with isocyanate paints. See **Figure 2-30**. The supplied-air device delivers purified air to the technician. The technician does not breathe air from the spray booth.

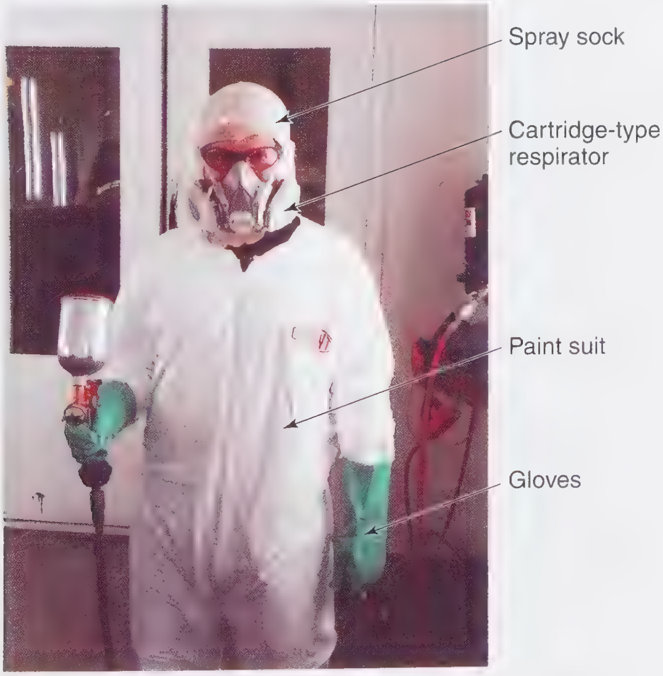


Figure 2-29. *This technician is wearing safety equipment that is appropriate when spraying paints that do not contain isocyanates.*

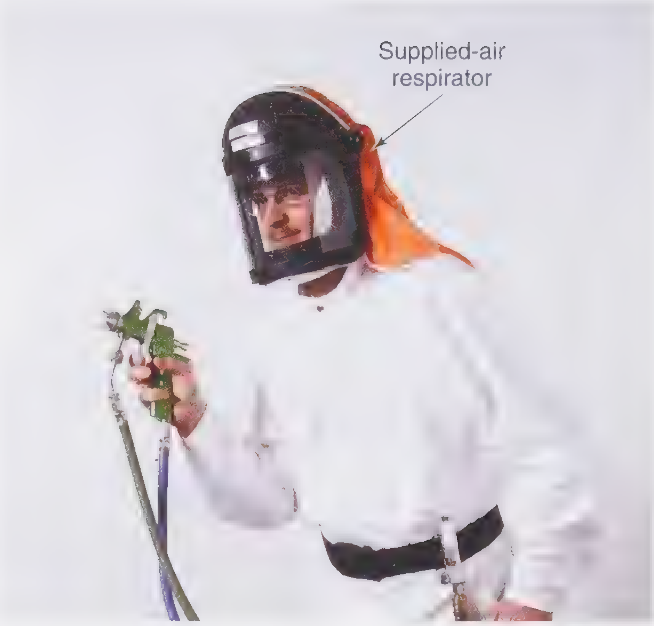


Figure 2-30. *This technician is wearing a supplied-air respirator. This equipment must be worn when spraying isocyanate-containing paint.*

Technicians must protect themselves from isocyanates. All spraying should be done in an approved spray booth or prep station. Spraying isocyanate paint in the open shop will expose unprotected technicians to isocyanates. Vapors from mixing paints must be removed with a power ventilation system. Mists from spraying must also be removed by power ventilation. Without adequate power ventilation, the isocyanates may be present in the air for hours or days after the paint is sprayed. Change the exhaust filters in the spray booth when they become filled with overspray dust. See **Figure 2-31**.

Mechanical Repair Safety

Mechanical repairs may involve working on a hot engine or working under the vehicle. Always wear appropriate protective gear when making mechanical repairs. For example, safety glasses should be worn when grinding or performing other tasks that may generate flying debris. Care must be taken when working near rotating components, such as the pulleys and drive shafts. Loose clothing or long hair can get caught in these components, pulling you into the spinning part and causing serious injury. Safety shoes should be worn to protect your feet from falling objects.

A running engine produces carbon monoxide. ***Carbon monoxide*** is a toxic gas that is colorless and

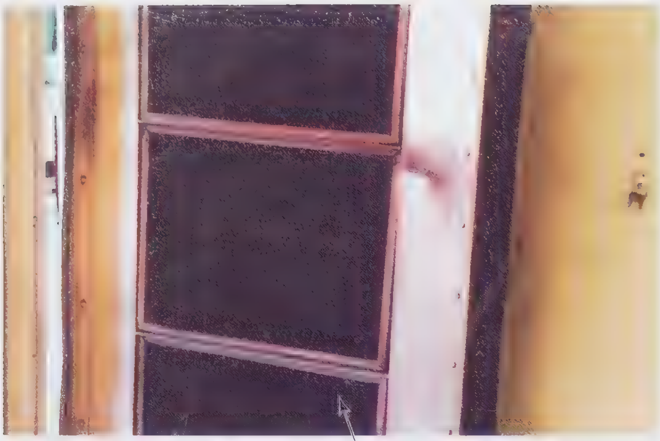


Figure 2-31. *These spray booth exhaust filters are clogged with overspray and should be replaced.*

virtually odorless. In small quantities, it can cause drowsiness and headaches. In large quantities it can kill. Never run an engine in an enclosed shop. If you must work on a running engine, move the vehicle outside or connect the vehicle's tailpipe to an exhaust gas ventilation system as shown in **Figure 2-32**.

In some cases, vehicles that are damaged in such a way that they will not run or roll can be moved with a floor jack. If necessary, place the damaged vehicle in neutral. Then lift the vehicle just high enough that the disabled wheels are off the ground and pull or push on the jack to move the vehicle.

A vehicle must often be raised to work beneath it. A lift can be used to raise a vehicle. A floor jack and jack stands can also be used to lift and secure a vehicle. With either method, always raise the vehicle at a recommended lift point. **Figure 2-33** shows lift points of a typical vehicle. On pickup trucks, the frame, engine cross member, and differential can be used as lift points. On a unibody vehicle, the unirails, radiator support, rocker panels, or rear differential can be used.

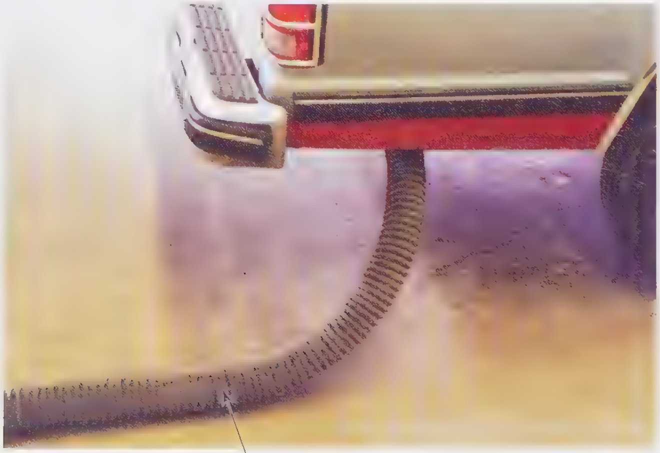


Figure 2-32. *This ventilation hose channels vehicle exhaust to the outside of the shop.*

Know the proper way to operate a lift. Lifts have instructions for proper use. Obtain the instructions and follow them carefully. Improperly positioned vehicles can fall off the lift. Lifts have built-in stops that prevent the arms from slipping down.

If a floor jack is used to raise a vehicle, properly position jack stands under the appropriate lift points. Then, lower the vehicle on the jack stands. Stay out from under the vehicle when positioning the jack stands. Only after the vehicle is lowered on the jack stands can you work under the vehicle.

Never crawl under a vehicle that is supported only by a floor jack. Vehicles weigh over 2000 pounds (900 kg). If a floor jack fails, the vehicle will drop to the ground, trapping and possibly killing anyone underneath.

Jack stands should be inspected for rust or broken welds before use. Floor jack handles should be kept in the up position at all times. A floor jack handle in the down position is a tripping hazard.

Hazardous Wastes

Collision repair and refinishing operations produce many hazardous wastes. These wastes include leftover paint, contaminated solvent, and used spray booth exhaust filters. Leftover paint is paint that was reduced but not used. Contaminated solvent is generated from spray gun cleaning. Spray booth exhaust filters become clogged with overspray.

A collision repair technician should always look for ways to reduce hazardous wastes. One way to reduce hazardous waste is to recycle contaminated solvent. A thinner recycler cleans contaminated thinner. The contaminated thinner is heated inside the recycler. The thinner, but not the contaminants, changes from a liquid to a gas. The clean thinner, in gaseous form, is then cooled. As the thinner is cooled, it condenses, or changes from a gas to a liquid. The recycled thinner can then be used to clean other spray guns. The contaminants from the recycling process can be disposed of as hazardous waste. However, some shops use the contaminants, which are just paint, as an undercoat or a sound deadener.

Another way to reduce the amount of hazardous waste generated and save spray gun cleaning time is to use a disposable spray gun cup liner. The plastic cup

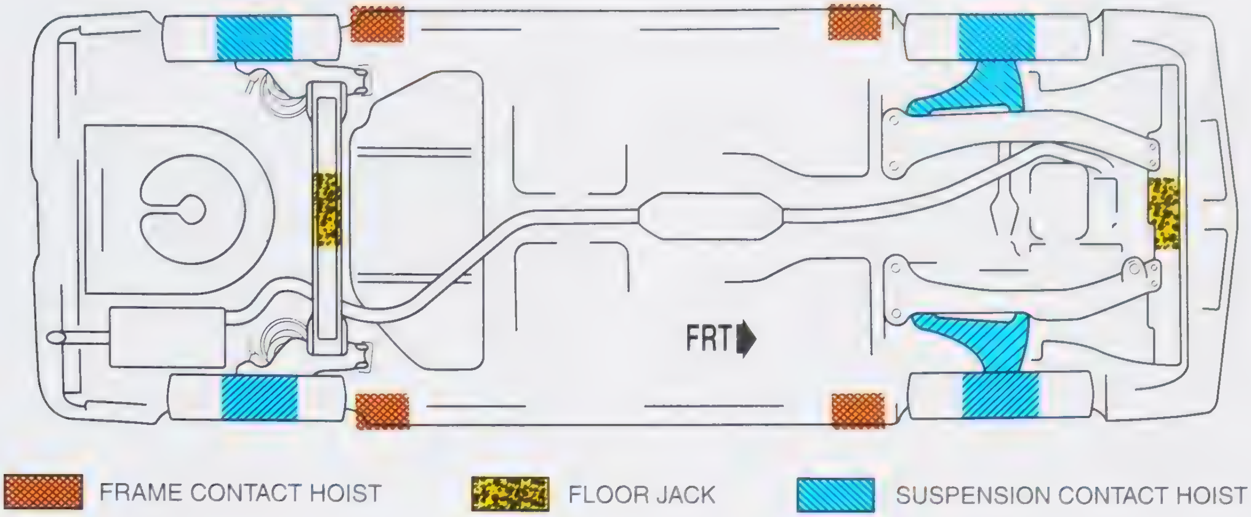


Figure 2-33. *This diagram shows lifting points for a specific vehicle.*

liner protects the spray gun cup from paint. After use, the cup liner is simply thrown away. When the liner is used, the only part of the spray gun that must be cleaned is the internal paint passage. This saves on thinner and time.

Spraying all the paint that is mixed will also help reduce hazardous wastes. For example, if a red paint is mixed for a job and not all the paint is used on the vehicle, the paint can be used on the next red car painted. The color may not match, but the paint can be used to cover up the undercoat and the proper color can be sprayed over it.

Environmental Regulations

The hazardous wastes generated by collision repair and refinishing operations must be disposed of properly to prevent damage to the environment. Federal and state governments have established regulations governing the ways hazardous wastes should be handled. Federal regulations apply throughout the United States. They form the basis of state regulations. State regulations can be more restrictive than the federal regulations but not less restrictive. Local regulations in each state follow the same guidelines. The local regulations must be at least as rigorous as the state regulations. They cannot be more lenient.

Environmental Protection Agency

The ***Environmental Protection Agency (EPA)*** helps protect human health and the environment by regulating industries that generate air, water, and land pollution. EPA regulations state that the collision repair shop is responsible for all hazardous wastes it generates. In fact, the shop has "***cradle-to-grave***" responsibility, which means the shop is responsible for hazardous material from the time it enters the shop until the hazardous waste is properly disposed of.

Most collision repair shops contract with a hazardous waste disposal company. The company moves the hazardous waste from the collision repair shop to the disposal site. See **Figure 2-34**. The waste paint and solvent is often incinerated. The collision repair shop, which is referred to as the ***generator***, is responsible

SERVICES
safety-kleen

Figure 2-34. *Hazardous waste disposal services, such as the one shown here, collect and dispose of hazardous wastes generated in the collision repair shop.*

for the waste even after the disposal company picks it up. If the company does not dispose of the waste in an approved manner, the shop is liable.

Each collision repair shop is required to have an EPA hazardous waste disposal number. This number allows the EPA to track the proper disposal of hazardous waste. The amount and type of hazardous waste produced determines which regulations the collision repair shop must follow. A Conditionally Exempt Small Quantity Generator produces less than 220 pounds (120 kg) of hazardous waste in a calendar month. These shops can store up to 2,200 pounds (997 kg) of hazardous waste. The waste must be kept in labeled containers and disposed of properly. A Small Quantity Generator produces between 220 and 2,200 pounds of hazardous waste per calendar month. The Small Quantity Generator can store up to 13,228 pounds (6000 kg) of hazardous waste up to 180 days. The requirements for the Small Quantity Generator are more demanding than those for the Conditionally Exempt Small Quantity Generator. These requirements include storing waste in a closed, labeled, compatible container, as well as having a plan for spills.

Volitile organic compound (VOC) laws are also EPA regulations that affect collision repair shops. VOCs are released into the atmosphere when paint is sprayed and while it dries. VOCs in the atmosphere react with sunlight to produce photochemical smog and ozone. The Environmental Protection Agency regulation of VOCs began with the Clean Air Act of 1990. In addition, some heavily populated areas in the United States, such as Southern California, required collision repair shops to use only HVLP spray guns in order to reduce VOC emissions.

In 1999, the EPA introduced the National Volatile Organic Compound Emission Standards for Automobile Refinish Coatings, commonly known as National Rule. The National Rule limits the amount of VOCs, measured in pounds per gallon, that can be in various types of paint. There are two ways the amount of VOCs can be specified for paint: as supplied and as applied. *As supplied* measures the amount of VOCs in the can, before the paint is mixed. Most paint must be mixed with a reducer or hardener before spraying. *As applied* measures the amount of VOCs in paint after the reducer or hardener has been added to create a sprayable mixture. Paint manufacturers formulate their products to comply with the National Rule.

Heavily populated areas in the United States must adhere to stricter EPA requirements. In addition to complying with the National Rule, shops in these areas must use HVLP spray guns, keep detailed records of wastes generated, and allow periodic spray booth inspections.

WORKING GREEN—
REDUCING VOCS

The National Rule will most likely be modified in the future, with greater restrictions on the VOC content of paints and regulations requiring the use of water-based basecoats. In the meantime, collision repair technicians can take steps to reduce the VOC emissions in the shop. One way to accomplish this is to use roll-on or spreadable undercoats, rather than sprayable undercoats. Undercoats that do not require spraying greatly reduce the number of VOCs released into the atmosphere.

Occupational Safety and Health Administration

The mission of the ***Occupational Safety and Health Administration (OSHA)*** is to make sure employers provide a safe and healthy work environment. To accomplish this, OSHA has established mandatory job safety and health standards. OSHA also regulates shop practices and shop equipment. Worksite inspections are one way to determine if these standards are met. Noncompliance can result in citations and/or penalties. OSHA also instructs employers on how to achieve compliance. Businesses may be required to keep records of work-related illnesses and injuries.

Right-to-know laws require employers to inform workers about the hazardous chemicals in the workplace. There are two sources of information about the chemicals used in the collision repair shop. The first is the label on a can of paint and other product. The label lists the hazards posed by the product, the safety equipment that must be worn while using the product, and the steps to take if the product is misused.

The other source of information is the ***material safety data sheet***, or ***MSDS***. The employer is required to have an MSDS for each product in the shop. The MSDS is provided by the product manufacturer. The MSDS is more detailed than the product's label. It lists the individual chemical components of the product and the hazards of each component. The firefighting and clean-up procedures are also listed. The employee has the right to ask the employer for the MSDS for any chemical product used in the shop.

Summary

- The technician must be aware of the hazards encountered in the collision repair shop and take steps to minimize the dangers associated with them.
- Chronic hazards cause problems after long-term exposure to a hazardous material. Acute hazards cause an immediate reaction.
- Good housekeeping and careful use of equipment will help prevent fires.
- Volatile liquids are the primary explosion hazard encountered in the shop. A volatile liquid evaporates readily when exposed to air.
- Volatile organic compounds cause air pollution and health problems for technicians.
- The primary chemical hazards encountered in the collision repair shop are found in paint products.
- Inhalation of isocyanates can lead to sensitization. Sensitization also occurs when isocyanates are absorbed through the skin or mucous membranes.
- Damaged or improperly used electric tools can cause an electric shock or electrocution.
- Loud noises produced in the collision repair shop can damage eardrums.
- Cuts, burns, and sprains are common collision repair shop injuries.
- Repetitive stress injury is the inflammation of muscles or tendons caused by performing the same action again and again.
- To reduce the risk of injury, appropriate personal protective gear should be worn when working in the collision repair shop.
- Safety glasses, safety goggles, and a face shield can be worn to protect eyes from particles and liquids.
- A dust mask should be worn when dry sanding. Cartridge-type respirators provide protection from some harmful vapors and mists. A supplied-air respirator is required when spraying isocyanate-containing paint.
- When using straightening equipment, never stand beside or straddle a chain that is under tension.
- Without power ventilation, isocyanates may be present in the air for hours or days after the paint is sprayed.
- Hazardous wastes produced in the collision repair shop include leftover paint, contaminated solvent, and used spray booth exhaust filters.
- The Environmental Protection Agency helps protect human health and the environment by regulating industries that generate air, water, and land pollution.
- The Occupational Safety and Health Administration was established to make sure employers provide a safe and healthy work environment.

Review Questions

Please do not write in this textbook. Place your answers on a separate sheet of paper.

1. A(n) ______ health hazard is caused by long-term exposure to a hazardous material.
2. Isocyanates are an acute hazard. True or False?
3. Name three things that are required to sustain a fire.
4. A Type ______ fire is caused by electrical equipment.
5. VOCs are the evaporating components in paint. True or False?
6. ______ paint contains less solvent than previous types of paint.
7. Inhalation of isocyanates will lead to ______.
8. A running engine produces carbon monoxide. True or False?
9. If a vehicle is raised with a floor jack, ______ must be placed under the vehicle before anyone works under it.
10. Why should high-top shoes be worn when welding and cutting?
11. A half-full oxygen tank does not need to be chained in place. True or False?
12. Explain what can occur if a hookup fails while a pull is being made.
13. A(n) ______ system can be used to reduce the amount of dust generated by power sanding.
14. Name four pieces of protective gear that should be worn when spraying non-isocyanate paints.
15. What is the purpose of right-to-know laws?

ASE-Type Questions

1. Technician A says that chemicals can enter the bloodstream through the skin. Technician B says that chemicals can enter the bloodstream by breathing in vapors. Who is right?
   (A) A only.
   (B) B only.
   (C) Both A and B.
   (D) Neither A nor B.
2. Burning paper is classified as a Type ______ fire.
   (A) A
   (B) B
   (C) C
   (D) D

3. All of the following can be used to put out a liquid fire EXCEPT:
   (A) dry chemicals.
   (B) water.
   (C) foam.
   (D) carbon dioxide.
4. Which of the following is created when paint is atomized?
   (A) Mist.
   (B) Vapor.
   (C) Concentration.
   (D) All of the above.
5. Which of the following contain isocyanates?
   (A) Body filler.
   (B) Paint catalyst.
   (C) Welding fumes.
   (D) Lacquer thinner.
6. Which of the following is a symptom of isocyanate sensitization?
   (A) Wheezing.
   (B) Coughing.
   (C) Shortness of breath.
   (D) All of the above.
7. A heavy bumper assembly must be lifted from the floor. Technician A bends his back when lifting. Technician B keeps her back straight and lifts with her legs. Who is right?
   (A) A only.
   (B) B only.
   (C) Both A and B.
   (D) Neither A nor B.
8. A tailgate will not open. Technician A wants to open the tailgate by striking it with his elbow. Technician B wants to open the tailgate by hitting it with a rubber hammer. Who is right?
   (A) A only.
   (B) B only.
   (C) Both A and B.
   (D) Neither A nor B.
9. What type of welding helmet shade is required when MIG welding?
   (A) #4.
   (B) #6.
   (C) #8.
   (D) #10.
10. A plasma cutter will be used to remove a quarter panel. Technician A wants to check the back of the quarter panel for insulation. Technician B wants to check the back of the quarter panel for undercoating. Who is right?
    (A) A only.
    (B) B only.
    (C) Both A and B.
    (D) Neither A nor B.
11. A bumper will be cut off with a cutting torch. Technician A wants to heat the gas-filled isolator so it can be easily removed. Technician B wants to remove anything flammable from the area before heating. Who is right?
    (A) A only.
    (B) B only.
    (C) Both A and B.
    (D) Neither A nor B.
12. Welding should be stopped ______ minutes before quitting time.
    (A) 5
    (B) 15
    (C) 30
    (D) 60
13. Technician A says that a floor jack handle should be kept near the floor. Technician B says that a floor jack handle should be kept in the “up” position. Who is right?
    (A) A only.
    (B) B only.
    (C) Both A and B.
    (D) Neither A nor B.
14. Because a collision repair shop produces hazardous waste, the shop is considered a ______ by the EPA.
    (A) regulator
    (B) resource
    (C) generator
    (D) facility
15. What is the name of the law that requires employers to inform workers of the hazardous wastes in the shop?
    (A) National Rule.
    (B) Right-to-know.
    (C) Cradle-to-grave.
    (D) ESQG.

Chapter 3

Vehicle Construction

Objectives

After studying this chapter you will be able to:

- Explain the different vehicle classifications.
- List the materials used to construct the automotive body.
- Identify the major assemblies of an automotive body.
- Summarize the vehicle production process.
- Describe vehicle safety ratings.

Technical Terms

alloy
aluminum
apron
bed side
body style
bows
bumper assembly
cab corner
center pillar
cowl
cowl vent panel
deck lid
door
drive train
engine cradle
fenders
flexible plastic
floor pan
full-frame vehicle
header panel
high-strength steel
hood
laminated glass
laminated steel
lower frame rail
magnesium
mild steel
non-structural part
quarter panels
radiator support
rear body panel
rear frame rail
rear hatch
rear pillar
rigid plastic
rocker panel
roof
sail panel
semi-rigid plastic
steel
structural part
strut tower
tailgate
tempered glass
trunk floor
unibody vehicle
upper frame rail
van side
vehicle safety rating
wheel house
windshield pillar

Introduction

This chapter explains the various vehicle classifications, describes the materials used to construct a vehicle's body, and identifies typical body components. It also provides a brief overview of the automobile manufacturing process. An understanding of the material presented in this chapter will help prepare you for the chapters that follow.

Vehicle Classifications

There are several ways to classify vehicles. In addition to the obvious classifications of year, make, and model, vehicles are often classified by construction type, body type, and drive train configuration. The following sections detail the most common vehicle classifications.

Vehicle Construction

One common way to classify vehicles is by the way they are constructed. Vehicles are commonly classified as either full-frame vehicles or unibody vehicles. A ***full-frame vehicle*** has a body and a separate frame. See **Figure 3-1**. The frame is made from steel or aluminum that ranges in thickness from 1/8"–1/4". The main body structure is made from 18–22 gauge sheet metal panels that are spot welded together. The body is mounted on rubber isolators and bolted to the frame. External panels are bolted in place on the main body structure and the frame. External panels include bumpers, fenders, doors, hoods and deck lids. These panels are made from steel, aluminum, or plastic.

A damaged welded panel on a full-frame vehicle can be replaced by drilling out the spot welds, removing the damaged panel, and welding a new panel in place. Damaged bolted panels can be replaced by unbolting and removing the damaged panel and bolting on a new panel. Full-frame vehicles include pickup trucks, as well as some sport utility vehicles, vans, and full-size cars. One drawback to vehicles with a full steel frame is that the frame is heavy. This weight reduces fuel economy. Aluminum frames weigh less than steel frames.

Unibody construction is used on most passenger cars. A ***unibody vehicle*** is constructed of sheet metal panels that are spot welded together to form the main body structure. See **Figure 3-2**. These panels provide the structural support for the vehicle, eliminating the need for a separate frame. Therefore, a unibody vehicle weighs less than a comparable full-frame vehicle, making it more fuel efficient. Unibody vehicles also have bolted-on external panels, such as fenders, hood, deck lid, doors and bumpers. Damaged panels on a unibody vehicle can be replaced in the same way they are replaced on the body portion of a full-frame vehicle. Most unibody vehicles are made of steel, but a few are made of aluminum.

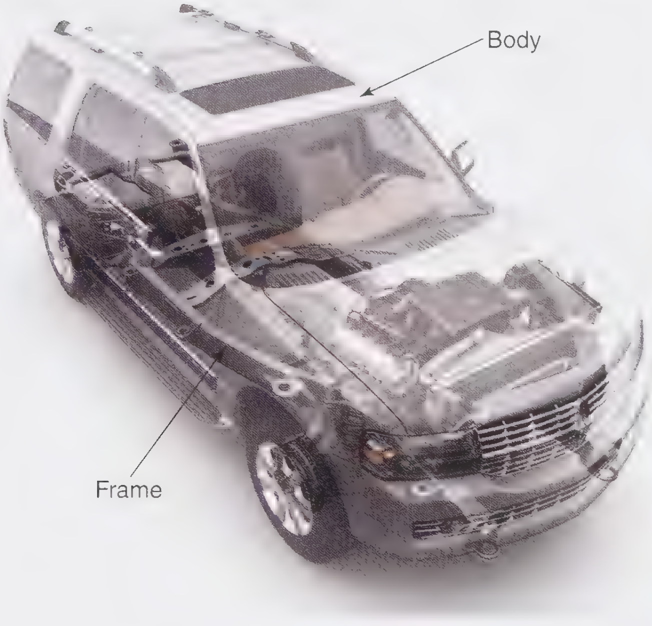


Figure 3-1. *This phantom view shows the body and frame of a full-frame sport-utility vehicle. The body is bolted to the frame. Isolators between the frame and body help minimize vibration transferred to the passenger compartment. (Ford)*

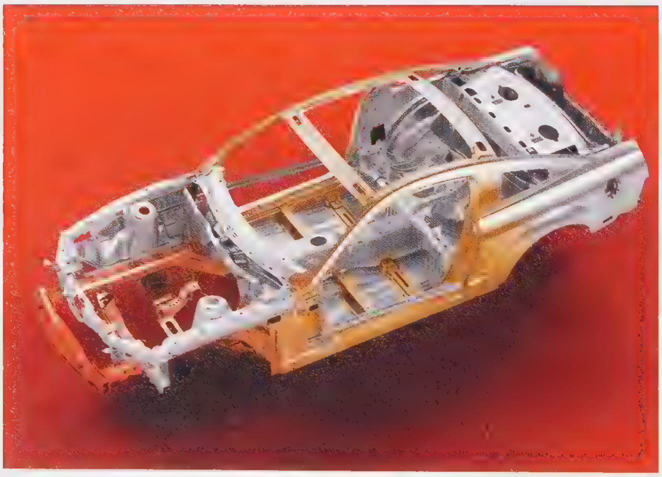


Figure 3-2. *The unibody consists of sheet metal panels that are welded together. (Ford)*

Drive Train Orientation

Another way to classify vehicles is by drive train orientation, **Figure 3-3**. The vehicle's ***drive train*** produces power and conveys this power to the drive wheels. In most vehicles, a gasoline or diesel engine produces the power. Although there are a few mid-engine vehicles, most vehicles have their engines mounted in the front. Most rear-wheel drive vehicles have a front-mounted engine that is mounted longitudinally (crankshaft centerline is parallel to the vehicle centerline). See Figure 3-3A. The engine powers the rear wheels. In a front-wheel drive vehicle, the engine mounted transversely (crankshaft centerline is perpendicular to the vehicle centerline), Figure 3-3B, and powers the front wheels. As its name implies, a four-wheel drive vehicle powers all four wheels. See Figure 3-3C. The engine in a four-wheel drive vehicle can be mounted longitudinally or transversely.

A new type of drive train configuration is a gasoline/electric hybrid. A hybrid vehicle is powered by a transversely mounted gasoline engine and an electric motor. The gas engine is relatively small, making it more fuel-efficient than a larger engine. Because the small gasoline engine is not very powerful, the electric motor assists the engine when more power is needed. There are two types of hybrids. A parallel hybrid, or full hybrid, can be powered by the gas engine only, the electric motor only, or both at the same time. In a series hybrid, or mild hybrid, the electric motor assists the gasoline engine during acceleration or going up a hill, but the electric motor alone does not power the vehicle.

Body Styles

Body styles are often taken into consideration when classifying vehicles, **Figure 3-4**. A vehicle's ***body style*** is determined by the configuration of its body panels. A typical sedan is shown in Figure 3-4A. A sedan can have two doors or four doors. The window glass in each door is surrounded by a channel. There is a pillar behind each front door. The doors close against these pillars.

A coupe is a two-door vehicle that does not have a channel surrounding the window glass. The coupe has a pillar behind each front door. See Figure 3-4B.

A station wagon has four doors and a roof that extends to the rear of the vehicle, enclosing the cargo area behind the back seat. A rear door provides access to the cargo area. This area is also accessible through the passenger compartment. Figure 3-4C shows a station wagon. A hatchback, Figure 3-4D, usually has two doors and a lift gate that allows access to the trunk

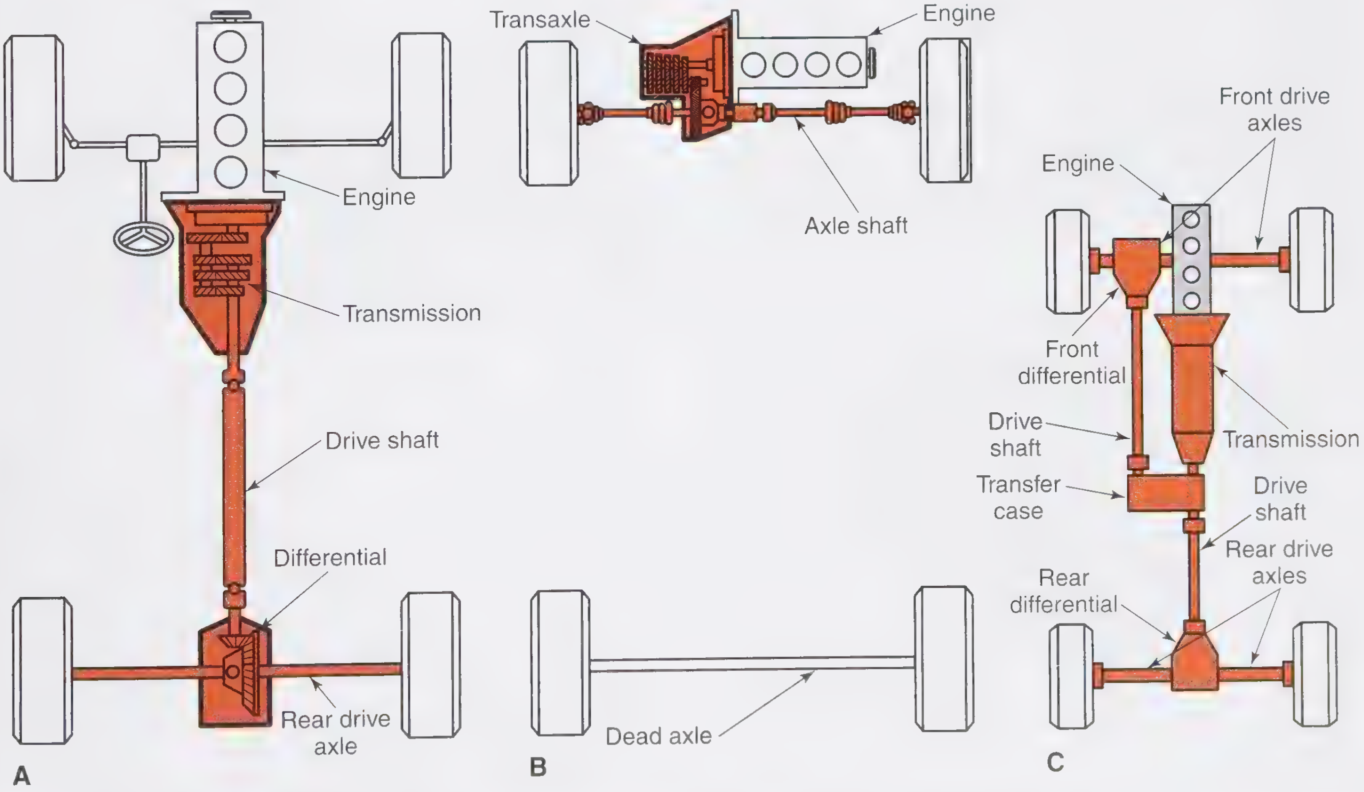


Figure 3-3. *Vehicles are commonly classified by drive train configuration. A—Rear wheel drive vehicle. B—Front wheel drive vehicle. C—Four-wheel drive vehicle.*

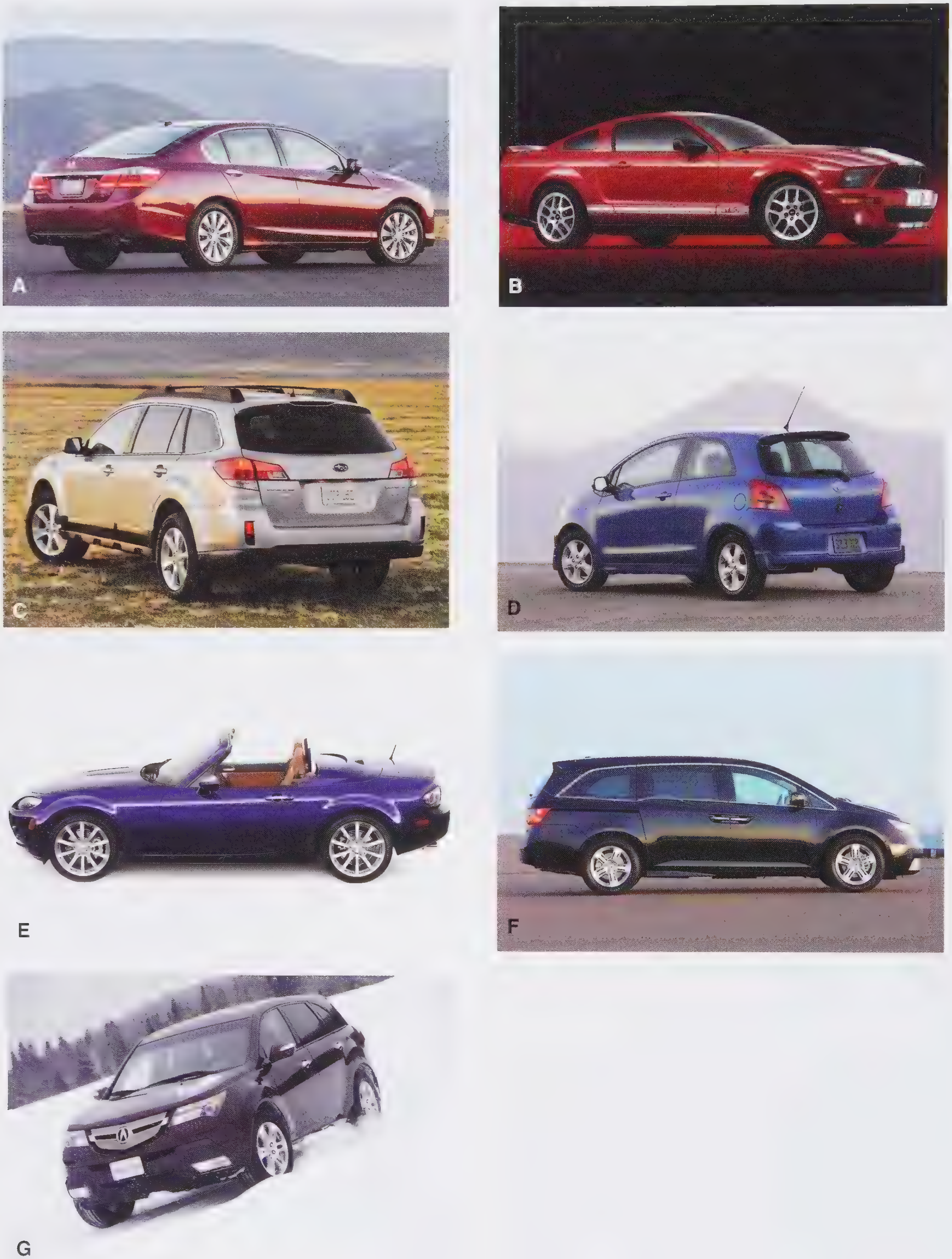


Figure 3-4. *Cars are commonly categorized by body style. Typical body styles for late-model vehicles are shown. A—Sedan. B—Coupe. C—Station wagon. D—Hatchback. E—Convertible. F—Minivan. G—Sport-utility vehicle. (Toyota, Ford, Subaru, Honda, Acura)*

area and the rear seat. Some manufacturers offer 4-door hatchbacks, which are similar to station wagons.

A convertible has a fabric top that can be folded down to allow open-air driving. When in the up position, the top protects the passenger compartment from the elements. A convertible is shown in Figure 3-4E.

A minivan has an enclosed body with a relatively high roofline, providing a great deal of interior room. The minivan may or may not have side windows, depending on its intended purpose. A minivan is shown in Figure 3-4F. Minivans are unibody vehicles.

Most sport-utility vehicles (SUV) have rugged full frames and are designed for off-road use. Because off-road driving requires high ground clearance, SUVs sit higher than cars. SUVs are generally four-wheel drive vehicles, but some are equipped with two-wheel drive. See Figure 3-4G.

NOTE

Many manufacturers are now producing crossover vehicles, which combine the desirable characteristics of an SUV with those of a car. Crossover vehicles are generally built on a car chassis rather than a truck chassis. Because they are lighter than traditional SUVs, crossover vehicles get better fuel economy than SUVs. Crossovers handle more like cars than SUVs, but have the cargo capacity and high seat positions that have made SUVs popular. However, they do not have the off-road driving capabilities of large truck-based SUVs.

A pickup truck has a cab and a bed that are generally mounted on a full frame. The cab contains the passenger compartment. The bed holds the cargo. Cabs are available as standard, extended, and 4-door models. See **Figure 3-5**. A pickup truck's bed can vary in length. In most cases, trucks with an extended cab or a 4-door cab have a shorter bed than comparable trucks with a standard cab. A compact or intermediate pickup truck will have a 6- or 7-foot bed, while a full-size pickup truck will have a 7- or 8-foot bed. Although the vast majority of pickup trucks are body-over-frame vehicles, there are a few unibody trucks on the market.

Pickup trucks are rated by cargo weight capacity. Cargo weight capacity is a measure of the weight a vehicle can safely carry. A half-ton pickup truck can carry a maximum of 1000 lb of cargo, a 3/4-ton pickup truck can safely carry up to 1500 lb, and a one-ton pickup truck can safely carry 2000 lb.

A full-size van is shown in **Figure 3-6**. It has an enclosed body, providing ample room for passengers or cargo. Depending on its application, a full-size van may or may not have side windows. Like pickup trucks, full-size vans are rated by cargo weight capacity.

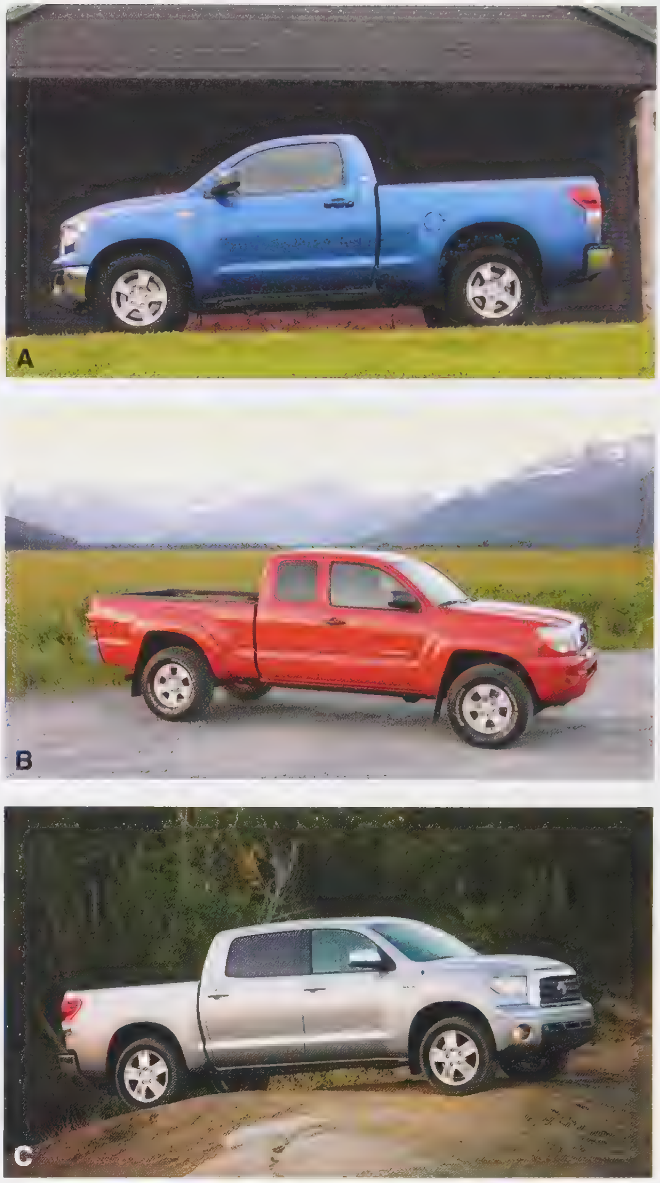


Figure 3-5. *A—A regular cab has one bench seat or two bucket seats. B—An extended cab is slightly longer than a regular cab and generally has small seats in the extended area. C—A four-door cab is much longer than a regular cab and has full-size seats for all occupants. (Ford, Toyota)*

Material Types

Vehicle designers constantly strive for ways to reduce vehicle weight without compromising occupant safety. Reducing the weight of a vehicle can help improve fuel economy. However, government safety standards require that vehicles be capable of protecting

Figure 3-6. *This is a full-size van. Since it is designed to transport passengers, it has side windows. (Ford)*

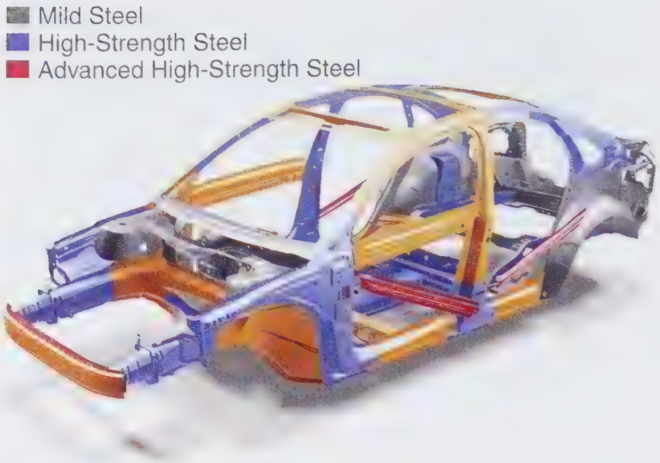


Figure 3-7. *Several different types of steel are used in the construction of this unibody vehicle. (Saab)*

the occupants in all types of collisions—front, rear, and side. The vehicle must also protect its passengers in the event of a rollover. To achieve these goals, today's vehicles are made from a variety of materials, including steel, plastic, glass, magnesium, and aluminum.

Steel

Steel is one of the most commonly used materials in the manufacture of today's vehicles. Steel is an alloy. An ***alloy*** is a metallic substance that consists of one metal and at least one other alloying element. Alloying elements are materials added to metals to give them desired properties. Iron is the primary metal in steel. Carbon is an alloying element. The amount of carbon and other alloying elements in steel determines its strength and other characteristics.

There are three basic types of steel used in automobile construction: mild steel, high-strength steel, and advanced high-strength steel. See **Figure 3-7**. The type of steel is determined by the types and percentages of alloying elements added to the steel, as well as the annealing procedure. Annealing is a controlled heating and cooling procedure that affects the hardness and strength of steel.

Mild steel has a carbon content of approximately 0.25%. Small amounts of other elements, such as manganese, silicon, or copper, may also be found in mild steel. Full frames may be made from mild steel. Body panels are also made from mild steel.

Yield strength is the amount of force required to permanently change the shape of metal. Mild steel has a yield strength of about 30,000 pounds per square inch (psi). Because mild steel has a relatively low yield strength, it is easily formed. Additional strength can be obtained by increasing thickness of the steel. Unfortunately, this also increases the overall weight of the vehicle. Crowns, body lines, and convolutions give mild steel body panels greater strength. Mild steel can be heated and welded with no loss of strength.

There are two types of mild steel used to manufacture vehicles, drawing steel (DS) and deep drawing steel (DDS). Drawing steel is the most common type of steel used on a vehicle. Deep drawing steel has lower yield strength than drawing steel, allowing it to be bent into complex shapes.

High-strength steel has a different chemical composition than mild steel. Additional alloying elements used in high-strength steel include manganese, phosphorus, sulfur, silicon, copper, nickel, chromium, and molybdenum. The carbon content of high-strength steel may be as high as 0.75%. There are two basic categories of high-strength steel: conventional high-strength steel and advanced high-strength steel.

With a yield strength of 50,000 psi, conventional high-strength steel is stronger than mild steel. Conventional high-strength steel allows panels to be made from thinner material, so vehicles weigh less. Less weight means better fuel economy. However, conventional high-strength steel is harder and more brittle than mild steel. Conventional high-strength steel can be used to make both structural and non-structural parts.

Great care is required when repairing damaged conventional high-strength steel components. Only moderately damaged conventional high-strength steel panels can be repaired and retain strength. The strength will be lost if a badly damaged conventional high-strength steel panel is straightened.

One type of conventional high-strength steel is high-strength, low-alloy steel (HSLA). High-strength, low-alloy steel contains very small amounts of carbon.

Instead, various combinations of alloys are used to produce various strengths of HSLA steels. The greater strength of a conventional high strength steel part compared to a mild steel part is caused by the small and uniform grain structure of the conventional high strength steel. HSLA steel parts are sensitive to heat. Heat in excess of vehicle manufacturers limits will change the small grains in HSLA to large grains and weaken the part.

Advanced high-strength steel contains different amounts and types of alloying elements than conventional high-strength steel. One distinctive alloying element used in advanced high-strength steel is boron. Advanced high-strength steel has yield point of *up to* approximately 200,000 psi. The grain structure of advanced high strength steel is different from the grain structure of conventional high strength steel. Advanced high strength steel has small islands, called microstructures, dispersed among the small grains. As with conventional high strength steel, advanced high strength steel is sensitive to heat. Body parts, such as door bumper brackets, crash beams and internal reinforcements inside pillars and roofs are made from advanced high-strength steel. Most damaged advanced high-strength steel components cannot be repaired; they must be replaced. Some types of advanced high strength steels are martensitic, dual phase (DP), and transformation induced plasticity (TRIP).

In order to protect the vehicle occupants with a stronger vehicle but to make the vehicle lighter for better gas mileage, the use of conventional and advanced high strength steel will increase in the future. In 2010 one vehicle manufacturer will produce vehicles composed of 50% conventional or advanced high strength steel and 50% mild steel compared to vehicles made of 5% conventional high strength steel and 95% mild steel in 1992.

Another type of steel used in vehicles is laminated steel. ***Laminated steel*** is made of two layers of steel bonded together with a solid layer of adhesive. The advantage of laminated steel over conventional single layer steel is less noise. Driving a vehicle and even just running the engine will cause the vehicle panels to vibrate. The vibration can be felt and heard by the vehicle occupants. Laminated steel reduces noise, vibration, and harshness (NVH) by damping the vibrations. The layer of adhesive adsorbs and does not transmit the vibrations, keeping the steel layers quiet. Laminated steel is used in the cowl and floor areas on some vehicles.

Depending on the application, both hot-rolled steel and cold-rolled steel are used in vehicle construction. Hot-rolled steel is formed by heating a relatively thick slab of steel and processing it through a series of rollers until the desired thickness is achieved. Hot-rolled steel is frequently used for frame rails, hinges, cross members, engine mounts, and other heavy applications where appearance is not an issue. Cold-rolled steel is manufactured by further processing hot-rolled steel. After the hot-rolled steel is cooled, it is again processed through another series of rollers. This time, however, the steel is not heated. Cold rolling achieves a more uniform thickness than hot rolling, with a much better surface finish.

Galvanized steel has a zinc coating. The zinc coating helps prevent the steel from rusting. Galvanized steel is used on many lower body parts.

Aluminum

The use of ***aluminum*** is increasing in vehicle construction. Some vehicles have aluminum body parts, such as the fenders, hood, deck lid, radiator support, engine cradle, and bumper reinforcement. Aluminum is only about one third the weight of steel, but it can be just as strong. Aluminum is easier to recycle than steel, but aluminum parts are more expensive than steel parts. Like steel, aluminum is an alloy. Alloying elements, including manganese, silicon, and magnesium, are added to produce desired characteristics such as strength or corrosion resistance.

Aluminum alloys are divided into two types: wrought and cast. Either type can be heat treatable or non-heat treatable. The shape of a wrought aluminum alloy part is formed using mechanical force to alter the arrangement of the molecules. Heat-treatable aluminum alloy is heated after forming for increased strength. The strength of non-heat treatable aluminum alloy is not affected by heat. Wrought-type aluminum alloy can be in the form of sheets or extrusions. Aluminum alloy sheets are pressed between rollers to achieve the desired thickness. The sheets are then shaped in a press. Component parts can be joined together to make an assembled part such as a hood. Extruded parts are formed by forcing softened aluminum alloy through a die. The die shapes the softened aluminum alloy to the design shape. A rocker panel is an example of an extruded part.

Cast aluminum alloy parts are made by adding liquid aluminum alloy to a mold. As the hot liquid aluminum alloy cools to a solid, it takes on the shape of the mold. A shock tower is an example of a cast aluminum part.

The strength of an aluminum alloy is determined by the type of aluminum (wrought or cast), the alloying elements, and the thickness of the part. Compared to steel, aluminum melts at a lower temperature (approximately 1,200°F [650°C] for aluminum alloy compared to 2,700°F [1480°C] for steel), transfers heat more readily, and does not change color when heated.

Slightly damaged aluminum panels can be repaired by heating, shaping, or welding. One type of vehicle has an aluminum full frame and another type of vehicle has an aluminum unibody. See **Figure 3-8**.

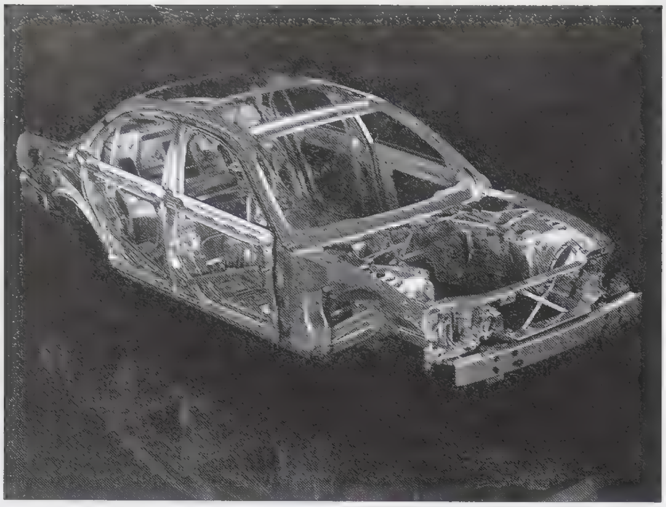


Figure 3-8. *Stamped sheet aluminium, aluminium alloy extrusions, and aluminium castings make up this unibody structure. A special rivet-bonding technique is used to connect the various part components. (Jaguar)*

Magnesium

Magnesium is lighter than aluminum, but it is just as strong. Parts made of magnesium include the radiator support for some pickup trucks and the instrument panel support in another type of pickup truck. Damaged magnesium parts should be replaced, not repaired. Never heat or weld a magnesium part, as the metal can catch fire.

Plastic

Many vehicle parts are made of plastic. Plastic components are lighter and more corrosion resistant than steel components. Plastic can be broken down into three general categories—flexible, semi-rigid, and rigid.

Flexible plastic can be easily distorted and returned to its normal shape after the pressure is released. See **Figure 3-9**. Flexible plastic is used on bumpers and ground effects. Flexible plastic can stretch and tear when damaged. Flexible plastic can dent. Highly curved and harder areas of a flexible plastic part, such as the corners of a bumper cover, may be pushed in and not pop back, creating a dent.

Semi-rigid plastic can be distorted, but not as easily as flexible plastic. It, too, will return to its normal shape after the pressure is released. If the force is great, a semi-rigid plastic part will break. Radiator fan shrouds and fender liners are generally made from semi-rigid plastic.

Rigid plastic is the least flexible type of plastic. This type of plastic will move little, if at all, before breaking. Rigid plastic is used to make rear hatches, doors, hoods, and cowl vent panels.

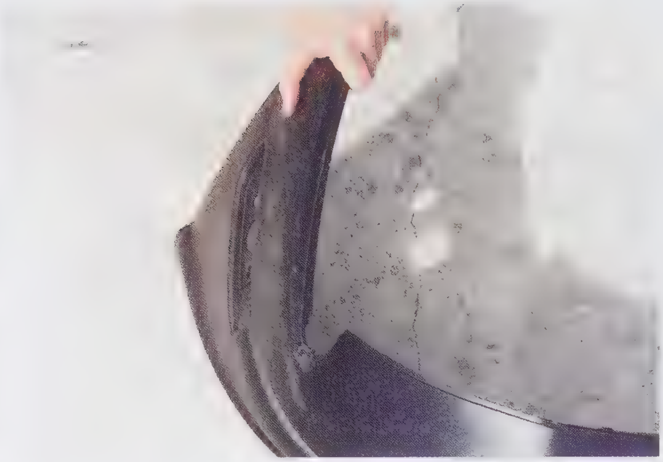


Figure 3-9. *This flexible plastic bumper can be distorted without damage.*

Glass

Glass can be much more than just a window. The glass used in a unibody vehicle is designed to strengthen the unibody. Glass can be classified as either fixed or movable. Fixed glass is set in place and cannot be opened. Windshields and back glass are examples of fixed glass. Most movable glass rolls up and down, but some van windows have glass that opens out.

There are two types of automotive safety glass: laminated and tempered. ***Laminated glass*** is made of two layers of glass with a layer of plastic in between them. Laminated glass is used for windshields. The plastic layer resists penetration and holds pieces of broken glass in place, helping to prevent injury. **Figure 3-10** shows what broken laminated glass looks like.

Tempered glass is a single layer of glass and is used on all windows except the windshield. It is harder than laminated glass and can withstand greater impacts. When tempered glass breaks, it shatters into small pieces, or shards, rather than long, jagged pieces. See **Figure 3-11**. The small pieces are less likely to cause injury to a vehicle's occupants.

Vehicle Parts

This section identifies the body parts of various types of vehicles. Keep the following in mind when reading about these body parts:

Left and right are always from the perspective of sitting in the driver's seat. The driver's side of the vehicle is the left and the passenger's side is the right.

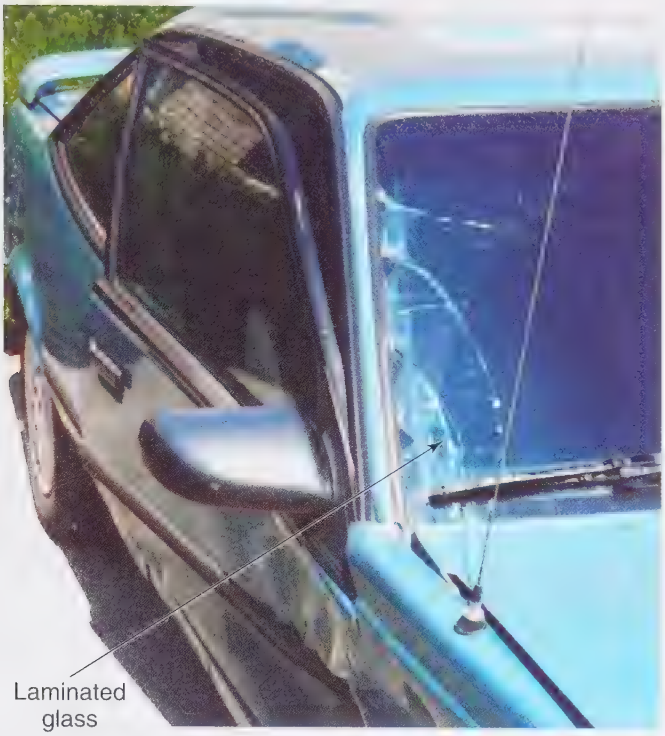


Figure 3-10. *The windshield glass is broken but it is held in place by the inner plastic layer.*

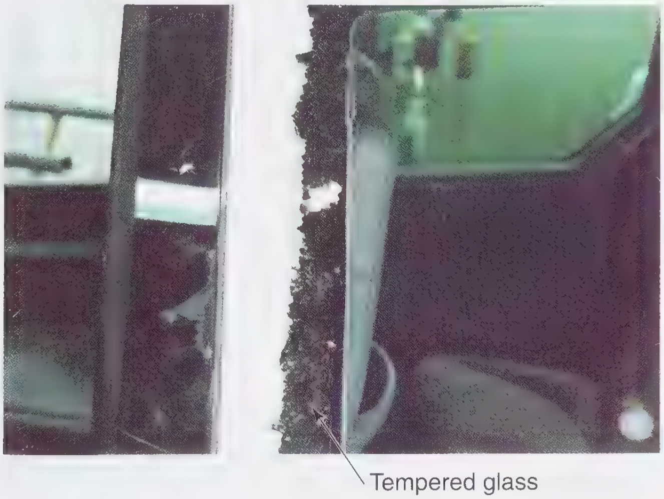


Figure 3-11. *The side glass in this minivan is broken. This tempered glass breaks into shards.*

- The front or back of a part is always referenced from the perspective of the part being installed on the vehicle.
- A ***structural part*** increases the strength of the vehicle. A ***non-structural part*** does not make a vehicle any stronger.
- An assembly is a group of individual parts.

Outer Body Assemblies

The outer body assemblies are readily visible when looking at the vehicle. These assemblies may or may not be structural parts, depending on vehicle design. Many of the common outer body assemblies are identified in **Figure 3-12**. Refer to this figure as the parts are described in the following sections.

A ***bumper assembly*** is located at the front and rear of the vehicle and is designed to protect the vehicle and occupants during minor impacts. The bumper assembly can be simple or complex. A simple bumper, sometimes called a face bar, is made of formed steel and is generally painted or chromed. A more complex bumper may have a plastic cover called a fascia, a reinforcement, and an impact absorber. See **Figure 3-13**. Turn signals and a grille may be mounted in the bumper assembly, as well. Bumpers are bolted to the frame or unibody. The ***header panel*** is also known as a headlight panel because the headlights are mounted in it. Not

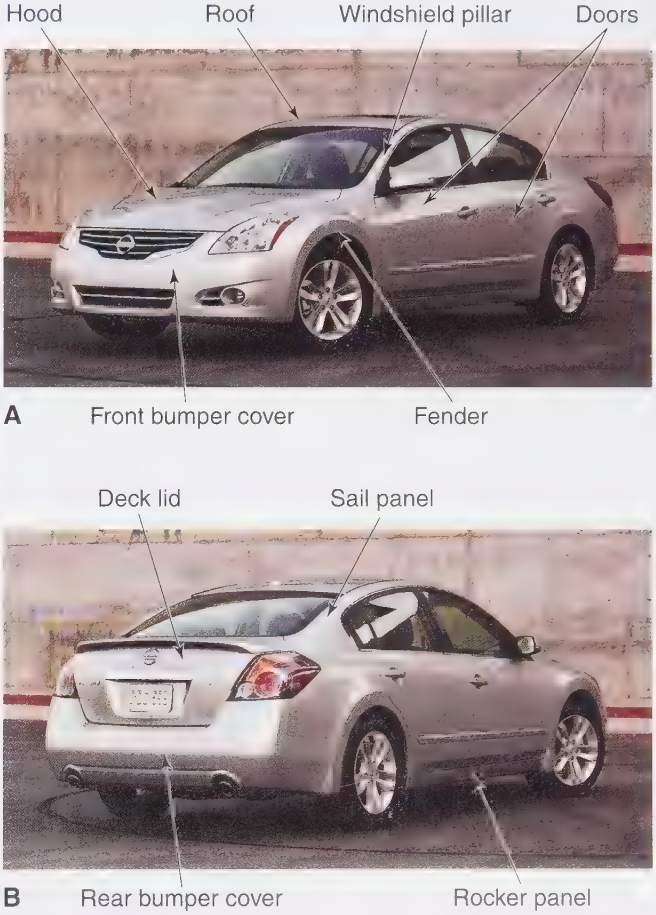


Figure 3-12. *Typical outer body assemblies found on a late-model unibody vehicle are shown. A—Front view. B—Rear view. (Nissan)*

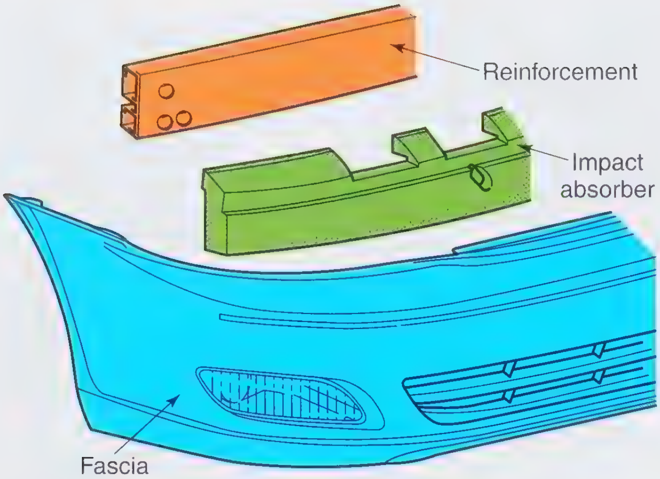


Figure 3-13. *This bumper assembly consists of a plastic fascia, a reinforcement, and an impact absorber. (Toyota)*

all vehicles have a header panel. The header is usually made of rigid plastic and is bolted in place.

Fenders are the outer body panels located between the front doors and the front bumper. They surround the front wheel openings and conceal front suspension components. Fenders may be made of steel or plastic. A fender may have a single skin or consist of inner and outer panels. The fender flange is the portion of the fender that is covered by the hood. Fenders are usually bolted in place.

The ***hood*** covers the engine compartment and is generally made of steel, aluminum, or rigid plastic. The hood is bolted to hinges that allow it to be opened and closed. A striker and latch secure the hood when it is closed. Some vehicles have a cowl vent panel. The ***cowl vent panel*** is located to the rear of the hood and is bolted in place. The panel may be made of steel or rigid plastic.

The ***roof*** covers the passenger compartment. Roofs are generally made of steel, but a few vehicles have a rigid plastic roof. A roof is welded in place and has ***bows*** for reinforcement.

A ***door*** has hinges that allow it to open and close, providing access to the passenger compartment. A striker and latch keep the door closed. The outer door panel, or door skin, can be repaired if damaged. The entire door, or door shell, can also be replaced. Door hinges may be bolted or welded in place.

The ***rocker panel*** is located under the door openings. On unibody vehicles, the rocker panel is a structural part. A structural rocker panel is a metal channel consisting of inner and outer panels with an internal reinforcement. Rocker panels are made out of steel. Ground effects may cover the rocker panel and are added to a vehicle for style. Pickup trucks and vans may have running boards mounted under the rocker panel. Running boards may be aluminum or plastic, while ground effects are usually plastic.

The ***quarter panels*** form the sides of the vehicles' body behind the side doors and surround the rear wheel openings. They can be made of steel or plastic. Steel quarter panels are welded in place. The quarter panel meets the roof at the sail panel. The ***sail panel*** connects the roof and the quarter panel.

The ***deck lid*** covers the trunk opening. It is hinged, allowing it to open and close, and is held closed by a latch and striker. Deck lids may be made out of steel or aluminum. Some vehicles have a rear hatch. A ***rear hatch*** is similar to the deck lid but contains the rear glass and is made from steel or rigid plastic. It is also hinged and bolted in place. See **Figure 3-14**.

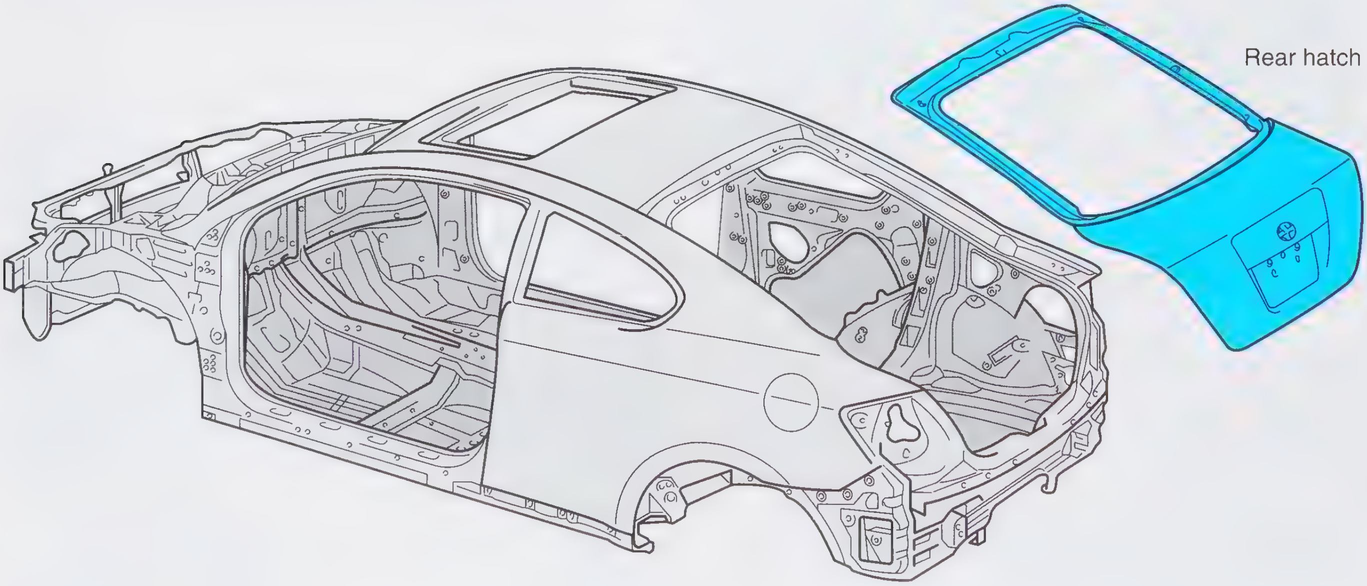


Figure 3-14. *The rear hatch is similar to the deck lid, but it contains the rear window glass. (Toyota)*

Pickup trucks have panels not found on cars. See **Figure 3-15**. A ***cab corner*** is found on a pickup truck and is located behind the door. The cab corner is made of steel and is welded to the rear panel of the cab. The ***bed side*** may be an outer skin, or it may include both inner and outer panels. A style-side bed side has no flare for the rear wheel. A flare-side, or step-side, bed side has a protrusion at the rear wheel. The rear fender on a step-side may be separate and replaceable. Bed sides are usually welded in place. Some bed sides have bolts and welds. A ***tailgate***, which closes the bed, is made out of steel, **Figure 3-16**. This vehicle part is held in place by the design of the bed and the tailgate.

A ***van side*** is usually a large steel panel that may or may not have window openings. A van side is shown in **Figure 3-17**. The van side is supported by internal reinforcement pillars. The van side is spot welded to the roof, rocker panel, and front and rear reinforcement pillars. Intermediate reinforcement pillars are attached to the van side with an adhesive. The adhesive bond holds the van side in place and minimizes vibration.

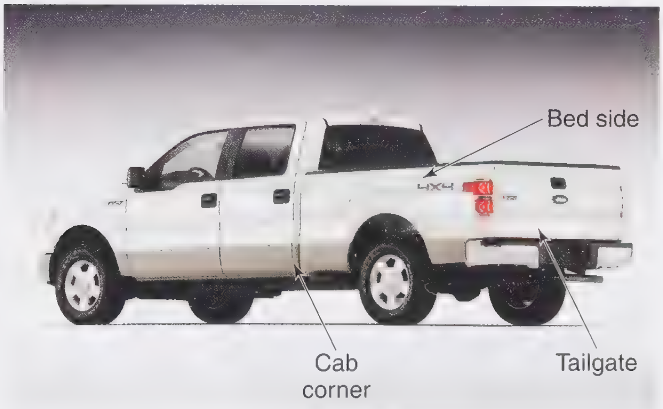


Figure 3-15. *Some of the panels on a pickup truck are different than those found on cars. (Ford)*

Figure 3-16. *Note the tailgate, which opens to allow cargo to be loaded into the bed. (Ford)*

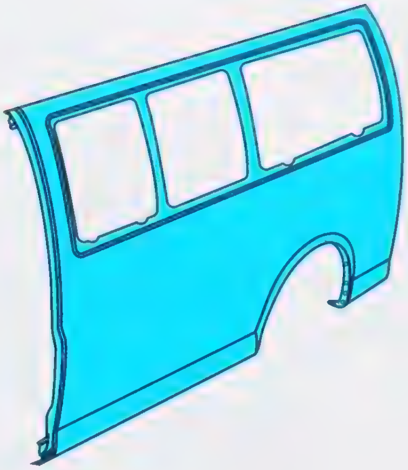


Figure 3-17. *This van side is for a passenger van. Note that it has openings for windows.*

Inner Body Assemblies

The inner body assemblies are not easily visible from outside the vehicle. Most are structural parts. Most are made out of steel. Some are made of high-strength steel. Typical inner body assemblies are discussed in the following section.

Many of the inner body assemblies found on a typical unibody vehicle are shown in **Figure 3-18**. The engine compartment, or front section, of the unibody vehicle consists of the radiator support, lower frame rails, upper frame rails, strut towers, and cowl. The ***radiator support*** holds the condenser and radiator. It may also provide a mounting for the headlights. On many unibody vehicles the radiator support is welded in place and forms an integral part of the strength of the vehicle. On other types of unibody vehicles and some full-frame vehicles, the radiator support is bolted in place.

The ***lower frame rail***, also called a lower front unirail, provides mountings for the drive train components. The lower front frame rail begins at the rear of the front bumper and is welded to the inner structure of the engine compartment and under the passenger's compartment. The lower front frame rail is a channel, with inner, outer, and reinforcing panels.

The ***upper frame rail*** adds strength to the upper portion of the engine compartment. It is welded to the radiator support and to the cowl. An upper frame rail is also a channel, but it is smaller than the lower front frame rail. The ***apron*** is a single panel that connects the upper and lower frame rails.

The ***strut tower*** supports the front suspension. The upper part of the McPherson strut is mounted to the strut tower. The location of the strut tower determines front end alignment. Therefore, correct positioning of the strut tower is essential.

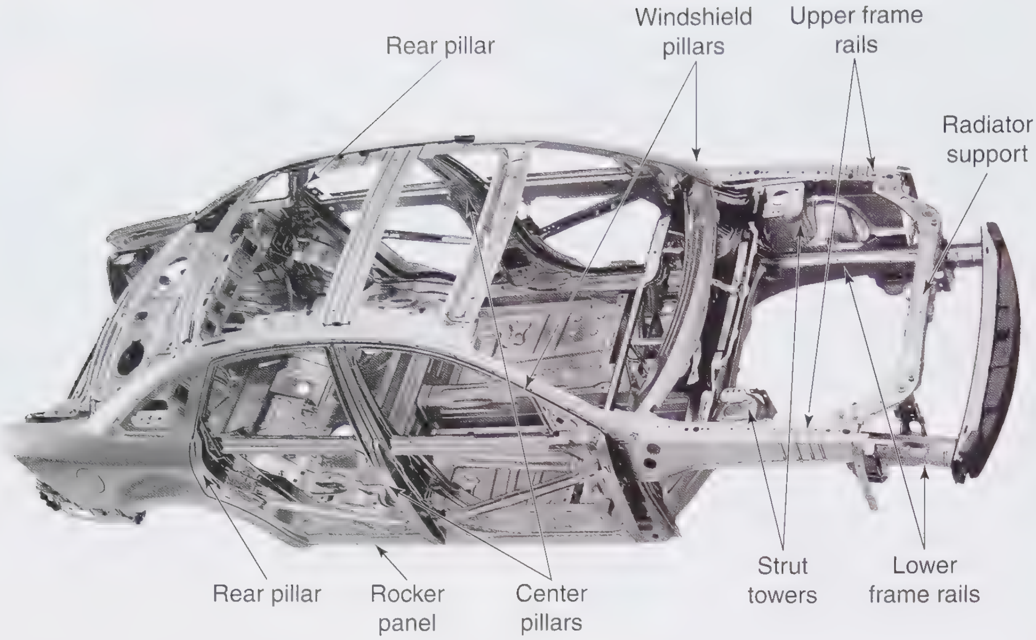


Figure 3-18. *Inner body assemblies found on a typical unibody vehicle. (Ford)*

NOTE

In some unibody vehicles, the drive train is mounted in an *engine cradle*. The engine cradle is similar in construction to a full frame and is bolted to the unibody, Figure 3-19. The engine, transmission, front suspension, and in some cases, the steering system are attached to the engine cradle. If the cradle is damaged, it can be replaced. The engine cradle may be made out of steel or aluminum.

The center section of a unibody vehicle consists of the cowl; floor; rocker panels; front, center, and rear pillars; and roof. The ***cowl***, or firewall, forms the front portion of the passenger's compartment. The ***windshield pillar***, also called the A pillar, is a structural part. It is a steel channel that consists of inner and outer panels and an internal reinforcement. The A pillar is welded in place. The A pillar portion of the cowl is where the front door hinges are mounted. The cowl is one of the strongest assemblies in the vehicle.

The ***center pillar***, or B pillar, which is found on four-door vehicles, is the part onto which the front door latches and the rear door hinges are connected. Center pillars are channels that are welded to the floor and roof.

The ***floor pan*** is the base of the passenger compartment. It is welded to the rocker panel and cowl. The floor pan has reinforced areas to which the seat belt anchors are mounted.

The ***rear pillar*** is the inner portion of the quarter panel. The door latches on the rear pillar. On a four-door vehicle, the rear pillar may be called a C pillar. The C pillar may form the inner reinforcement for the sail panel. The C pillar is welded to the floor and the roof.

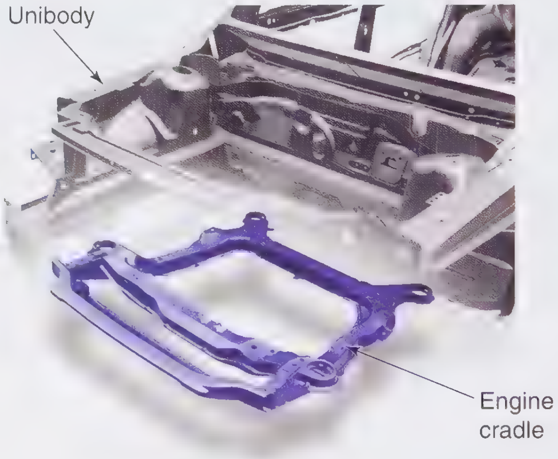


Figure 3-19. *This engine cradle provides additional support for the drive train and front suspension components. (Ford)*

The rear section is formed by the rear pillars, rear frame rails, wheel houses, floor, and rear body panel. See **Figure 3-20**. The ***rear frame rail***, which provides support for the rear portion of a unibody vehicle, is a channel consisting of inner and outer panels and possibly a reinforcement. The rear suspension may be mounted to the rear frame rails. A ***wheel house*** surrounds the rear wheel. It is formed from two panels, an inner panel and an outer panel, that are welded together. The outer portion of the wheel house is welded to the quarter panel. The ***trunk floor*** is welded to the inner wheel house panels and to the rear frame rails. The rear suspension may be

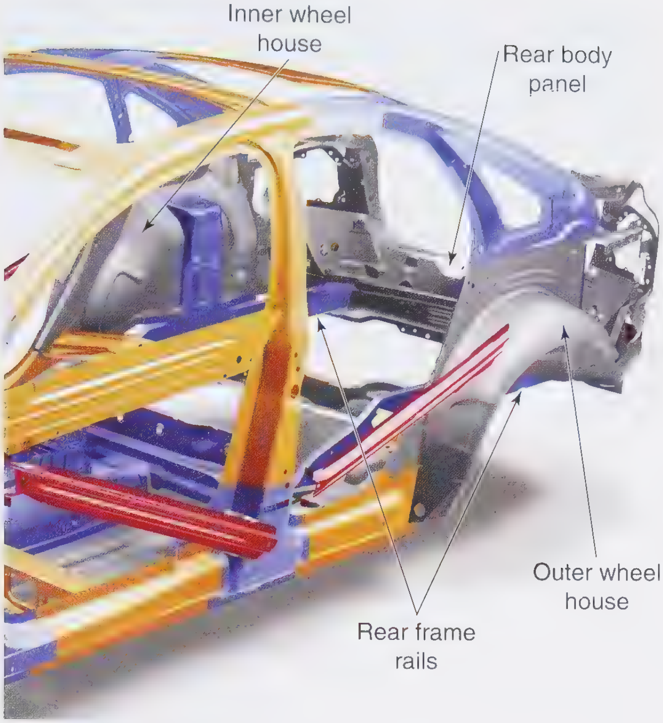


Figure 3-20. *The rear section of a unibody vehicle is formed by the rear pillars, rear frame rails, wheel houses, floor, and rear body panel. (Ford)*

mounted to the inner wheel house. The ***rear body panel*** is welded between the quarter panels and forms the rear portion of the vehicle below the deck lid. The taillights and the license plates may cover up the rear body panel.

On full-frame vehicles, such as a pickup truck, the front section is the portion of the vehicle under the hood, the center section is the cab, and the rear section is the bed. A full frame, **Figure 3-21**, provides support for the vehicle's body and drive train components. A damaged full frame can be replaced. The side rails may be boxed in one area for added strength. Some full frames are made so that the damaged portion can be replaced as a section. In some frames, front sections can be replaced. The frame consists of two side rails joined by cross members. Some cross members are replaceable. Cross members may be riveted or welded to the side rails.

Vehicle Production

While it is not within the scope of this textbook to explain in detail how a vehicle is manufactured, this section will provide a brief overview of the manufacturing process. A general understanding of how a vehicle is made will help you understand how to repair damage.

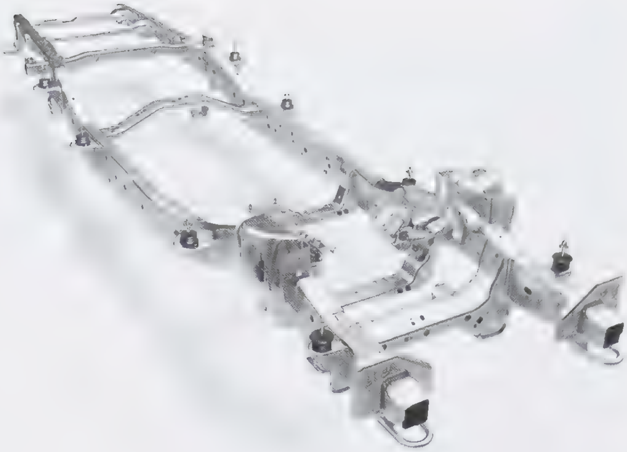


Figure 3-21. *This steel frame is typical of those used in late-model pickup trucks. (Ford)*

During vehicle production, sheet metal panels are stamped by large machines called presses. The presses form the sheet metal into the desired shapes, such as single-piece fenders. Complex parts such as doors, unibodies, and pickup truck cabs are made from several stamped panels that are welded together. The panels are fitted into a jig. The jig holds the panels in the proper alignment for welding. The parts are spot welded together by an electric welder. See **Figure 3-22**. Weld bonding is also used to join component panels together. In weld bonding, an adhesive is applied to the panels, the panels are fitted together, and then they are electric spot welded together. Some structural parts are joined by a continuous MIG weld. The MIG weld is usually not longer than 1".

Laser welding joins panels together. This method allows panels of different thicknesses and strengths to be joined without any overlap. The laser weld looks like thin line where the two panels meet. An example of a laser welded panel is the one-piece door opening panel on an extended cab pickup truck. The door opening panel extends from the A pillar to the cab corner and includes the outer rocker panel and part of the roof. The door opening panel is made of several differently shaped pieces laser welded together. The roof piece is thinner than the A pillar piece. Laser welding allows the manufacturer to vary the design strength within one panel.

Welding is not the only way that panels, even structural panels, can be joined. Aluminum panels together are sometimes joined by riveting. The rivets are self-piercing, so no hole is required for insertion. The rivets eliminate the need for welds.

Full frames can be made by stamping a flat sheet of steel into a C shape. Two stamped C shapes can be welded together to form a box. Another way to form a full frame box is by hydroforming. In hydroforming, a rectangular steel tube is formed into a complex shape using hydraulic pressure.

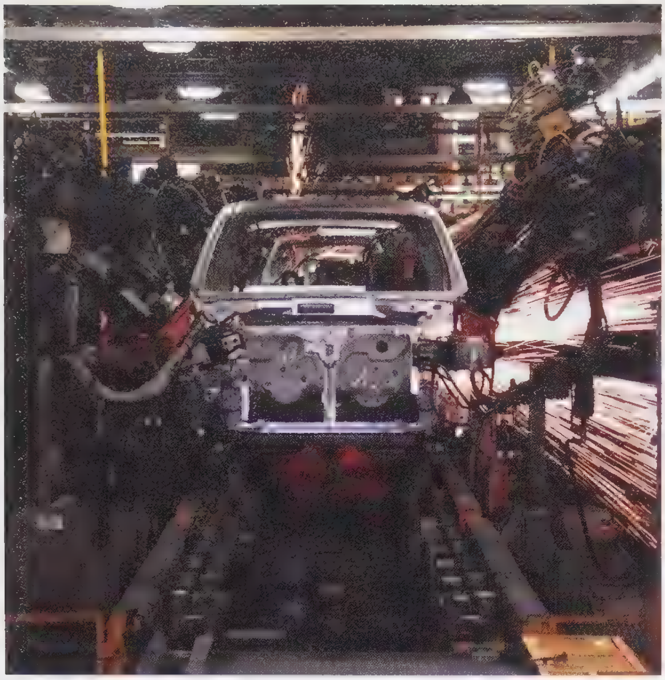


Figure 3-22. *After a vehicle's body panels are stamped at the factory, they are assembled and welded together as shown here. (Ford)*

On many full-frame vehicles, only a portion of the frame, such as the front section, is hydroformed. The rest of the frame is made of stamped steel. The stamped steel sections and the hydroformed sections are welded together. Certain portions of a frame may be made from stronger steel than other portions of the same frame.

Once the unibody vehicle is welded together or the cab or body is mounted on the full-frame vehicle, the bolt-on parts can be installed. Bolt-on parts include the hood, fenders, doors, deck lid, and bumpers.

The vehicle panels must be protected from corrosion. One way to protect is to use galvanized steel in areas subject to corrosion, such as the rocker panels. Additional protection is added during the manufacturing process. The vehicle is dipped in corrosion-resistant primer. The seams where panels join are filled with a sealer to keep out contaminants. The entire vehicle is sprayed with a durable paint finish, **Figure 3-23**.

After the vehicle is painted, the interior, drive train, electrical wiring, and glass are installed. See **Figure 3-24**. Some vehicles have rigid or structural foam inside body cavities such as the rocker panels, unirails, and center pillars. Structural foam is molded to the internal shape of the cavity. The structural foam transfers some energy in a collision, adding strength and stiffening the part. Rigid foam also stiffens the part but does not contribute to the overall strength of the vehicle. Stiffening of the parts with internal cavities makes the vehicle feel more solid and ride better without making the vehicle significantly heavier.

Vehicle Safety Rating

A ***vehicle safety rating*** is a measure of a vehicle's crashworthiness. It is determined by measuring the amount of damage a vehicle sustains and the potential for occupant injury that occurs when the vehicle is subjected to standardized tests. There are four basic types of safety ratings: frontal impact, side impact, roof strength, and rear impact.

To arrive at the frontal impact rating, the two standardized collision tests are performed: the full-width frontal test and the frontal offset test. The full-width frontal test is the standard in the United States, while the frontal offset test is the standard in other countries, such as Japan and Australia. In the full-width frontal test, two test dummies are positioned in the front seat or seats of a vehicle and the vehicle is propelled into an unmovable barrier at 35 mph. The entire front of the vehicle hits the barrier. The movement of each dummy is measured to determine the potential for injury to the head, chest, and legs. If the dummies have less than a 10% chance of sustaining a life threatening injury, the vehicle receives a 5-star front impact safety rating.

In the frontal offset test, only 40% of the driver's side of the front of the vehicle, which is moving at 40 mph, hits the barrier. The barrier is not totally rigid. Instead, the vehicle impacts a deformable aluminum face on the barrier. The amount of deformation in the vehicle's passenger compartment, overall damage to the vehicle, and the movement of the dummies are evaluated. The vehicle safety rating of good, acceptable, marginal, or poor is calculated by factoring in many criteria such as whether the test dummies heads were partially ejected from the vehicle, if the test dummies chests hit the dashboard, if the fuel system leaks, if the floor moves back

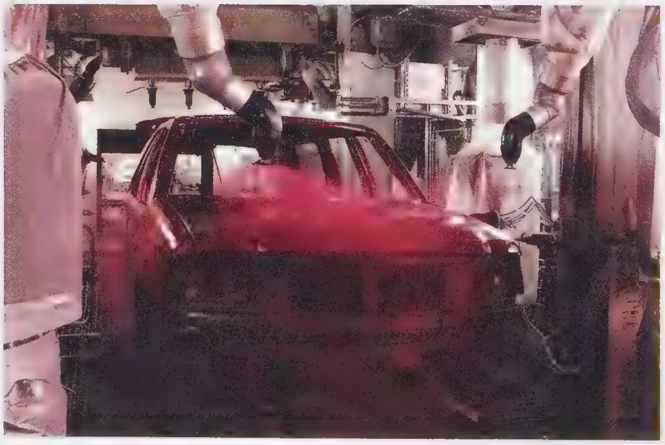


Figure 3-23. *After a vehicle's body has been assembled, it is primed and painted to help prevent rust and corrosion. (Ford)*

Figure 3-24. *These assembly line employees are positioning the front windshield on a newly assembled vehicle. (Ford)*

and traps the test dummies feet, or if the hood moves back into the passenger compartment.

There are two tests used to determine the side impact rating. In one test, the vehicle is stationary and a 3000-lb sled moving at 38 mph hits the driver's door at an angle of approximately 60°. The movement of the test dummies is measured. In the other side impact test, the vehicle is stationary and a 3300-lb movable barrier moving at 31 mph slams perpendicularly into the driver's door. The barrier has the shape of the front bumper, fenders, grille and hood of an SUV or pickup truck. The barrier is not rigid; it deforms on impact. As with the frontal offset test, the damage to the vehicle and the forces on the test dummies are evaluated to arrive at a good, acceptable, marginal, or poor rating.

During the roof strength rating test, the vehicle is parked under a large metal plate. The underside of the vehicle is supported so the suspension does not compress. Hydraulic force pushes the metal plate on the side of the roof over the driver's head. The roof is compressed 5". During the compression the windshield will crack and the side windows will blow out. The amount of force required to cause 5" of crush is measured and compared to the vehicle weight. A force-to-weight ratio is then calculated. If a force equal to or greater than 4 times the vehicle weight is required to cause the compression, a ratio of 4:1 or more, the vehicle is given a good rating. If the force-to-weight ratio ranges from 3.25:1 to 3.9:1, the vehicle is given an acceptable rating. Vehicles with ratios of 2:5:1 to 3.24:1 are rated as marginal. If the ratio is below 2.5:1, the vehicle is rated as poor.

The rear impact rating is not determined by vehicle deformation; instead it is based on the potential for head, neck, and upper body injury to vehicle occupants. There are two testing methods used to determine the rear impact rating. The first testing method, called the geometry test, looks at where the headrests would contact the back of an average person's head. A contact location above the center of the head is good, at the center of the head is acceptable, and below the center of the head is either marginal or poor. The second testing method used to determine the rear impact rating involves performing a crash test. Crash dummies are belted into seats mounted on an impact sled. The sled is then accelerated to simulate a rear impact in which a stopped vehicle (0 mph) is hit in the rear, causing it to accelerate to 10 mph (a 10 mph change in velocity). An impact of this type will cause the occupants' heads to snap back. Injury to the crash dummies is measured to calculate the rear impact rating.

Summary

- There are several ways to classify vehicles. In addition to year, make, and model, vehicles are often classified by construction type, body type, and drive train configuration.
- A full-frame vehicle has a body and a separate frame.
- A unibody vehicle is constructed of sheet metal panels that are spot welded together to form the main body structure.
- The vehicle's drive train produces power and conveys this power to the drive wheels.
- A vehicle's body style is determined by the configuration of its body panels.
- Vehicle designers constantly strive for ways to reduce vehicle weight without compromising occupant safety.
- There are three basic types of steel used in automobile construction: mild steel, high-strength steel, and advanced high-strength steel.
- Laminated steel is made of two layers of steel bonded together with a solid layer of adhesive.
- Aluminum is only about one third the weight of steel, but it can be just as strong.
- Magnesium is lighter than aluminum, but it is just as strong.
- Plastic can be broken down into three general categories—flexible, semi-rigid, and rigid.
- Laminated glass is made of two layers of glass with a layer of plastic in between them. Tempered glass is a single layer of glass and is used on all windows except the windshield.
- A structural part increases the strength of the vehicle. A non-structural part does not make a vehicle any stronger.
- The outer body assemblies are readily visible when looking at the vehicle. These assemblies may or may not be structural parts, depending on vehicle design.
- The inner body assemblies are not easily visible from outside the vehicle. Most are structural parts.
- There are four basic types of safety ratings: frontal impact, side impact, roof strength, and rear impact.

Review Questions

Please do not write in this textbook. Place your answers on a separate sheet of paper.

1. In a front-wheel drive vehicle, the engine is mounted ______, meaning the centerline of the engine crankshaft is perpendicular to the centerline of the vehicle.
2. What are the two power sources in a hybrid vehicle? A hybrid vehicle relies on a(n) ______ engine and a(n) ______ motor for power.
3. ______ is a controlled heating and cooling procedure that affects the hardness and strength of steel.
4. What are the advantages of making automotive body parts from aluminum?
5. The fender flange is under the hood. True or False?
6. ______ glass is a single layer of glass that breaks into shards.
7. The driver's side is the left side of the vehicle. True or False?
8. A plastic bumper cover is also called a(n) ______.
9. The ______ covers the engine compartment.
10. A full frame consists of ______ and cross members.
11. The ______ provides a mounting surface for the upper portion of the McPherson strut.
12. The ______-pillar is the center pillar on a four-door vehicle.
13. During vehicle production, sheet metal panels are stamped by large machines called ______.
14. A(n) ______ holds parts in proper alignment during vehicle manufacture.
15. The plastics used to make vehicle parts can be broken down into three basic categories. Name them.

ASE-Type Questions

1. What most commonly joins the structural panels of a unibody?
   (A) Spot welds.
   (B) Adhesives.
   (C) Bolts.
   (D) Nuts.
2. Which of the following is not mounted in the engine cradle?
   (A) Engine.
   (B) Transmission.
   (C) Front suspension.
   (D) Cowl vent panel.
3. Which of the following body styles has a lift gate?
   (A) Convertible.
   (B) Sedan.
   (C) Hard top.
   (D) Hatchback.
4. Each of the following components may be made out of rigid plastic EXCEPT:
   (A) rear hatch.
   (B) hood.
   (C) cowl vent panel.
   (D) tailgate.
5. Technician A says that the rear license plate is mounted on the front of the rear bumper. Technician B says that the rear license plate is mounted on the rear of the rear bumper. Who is right?
   (A) A only.
   (B) B only.
   (C) Both A and B.
   (D) Neither A nor B.
6. A four-door vehicle has ______.
   (A) no C pillar
   (B) A, B, and C pillars
   (C) no B pillar
   (D) A and C pillars only
7. Technician A says that the front lower frame rail is also called a unirail. Technician B says that the engine cradle is mounted to the front lower frame rail. Who is right?
   (A) A only.
   (B) B only.
   (C) Both A and B.
   (D) Neither A nor B.
8. Which of the following are used to connect the full-frame side rails?
   (A) Aprons.
   (B) Cross members.
   (C) Lower frame rails.
   (D) Pillars.
9. Which of the following parts hold the condenser?
   (A) Apron.
   (B) Radiator support.
   (C) Shock tower.
   (D) Sail panel.
10. In a four-door sedan, the front doors close against the ______.
   (A) sail panel
   (B) fender
   (C) pillar
   (D) quarter panel

Chapter 4

Fundamentals of Collision Damage

Objectives

After studying this chapter, you will be able to:

- Describe the various factors that will influence the way a vehicle will react in a collision.
- Identify bends, body lines, and crowns.
- Differentiate between direct and indirect damage.
- Explain the bend-versus-kink rule.
- Describe the types of collision damage found on full-frame and unibody vehicles.

Technical Terms

arrowhead
bend
bend-versus-kink rule
body line
buckle
collapsed-hinge buckle
combination crown
crown
dent
diamond
direct damage
elastic deformation
elasticity
force
grains
impact angle
indirect damage
inertia
inertia damage
kickup
kink
lateral force
longitudinal force
mash
plastic deformation
plasticity
sag
sidesway
simple rolled buckles
surface area of impact
target
twist
upset
vehicle height
work hardening
yield point

Introduction

This chapter will introduce you to the fundamentals of collision damage. It will discuss the properties of the various types of metal used in vehicle construction and detail the way that the shape of body panels and structural components impact the way they react when damaged. It also explains the factors that determine the amount of damage that occurs when a vehicle is involved in a collision. Finally, the types of damage that occur in full-frame and unibody vehicles will be discussed.

Vehicle Design Factors

Vehicle design factors influence the way a vehicle will react in a collision. These factors include the properties of the metals used in vehicle construction and the way these metals are shaped.

Metal Properties

The properties of the metals used in a vehicle will affect the amount of damage that occurs when the vehicle is involved in a collision. A basic understanding of these properties will help you assess and repair collision damage.

If a piece of metal is examined under a microscope, units called grains will be visible. ***Grains*** are formed by the crystalline pattern of the metal and alloy molecules. Different types of metals have different grain patterns. For example, mild steel has a large, loose grain pattern, **Figure 4-1**. High-strength steel, on the other hand, has a small, tight grain pattern. See **Figure 4-2**. The types and amounts of alloying elements added to metal and the annealing process determine the grain pattern. During the steelmaking process, a uniform grain pattern will be set in the metal. When the metal is formed into a part, the grain pattern is changed in areas that have a bend or a stretch. Differences in grain pattern in a bend or stretch translate into differences in the metal's properties in these areas.

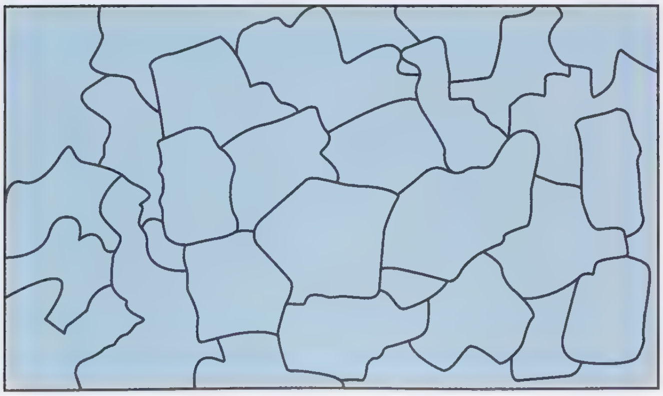


Figure 4-1. *When viewed under a microscope, mild steel has a large, loose grain pattern.*

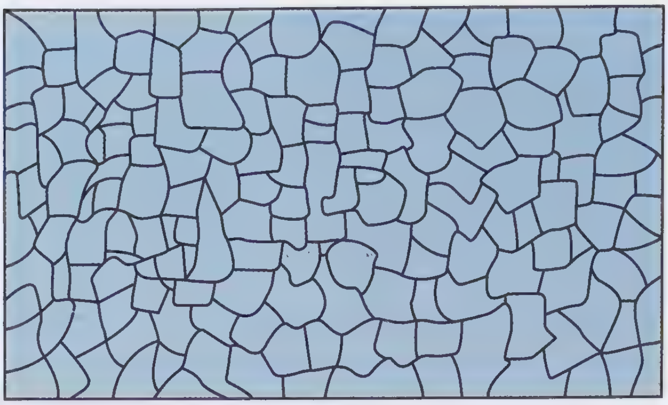


Figure 4-2. *High-strength steel has a small, tight grain pattern when viewed under a microscope.*

Elasticity

Elasticity is the ability of a metal to bend without permanent deformation. If force is applied to one end of the metal and does not move the metal beyond its yield point, the grain arrangement will not change, and there will be no permanent deformation. See **Figure 4-3**. The strip will spring back to its original shape because movement in the grains is not great enough to arrange them into a new set.

Different types of sheet metal have varying degrees of elasticity. Some variables in the elasticity of sheet metal include the types of alloying elements and annealing procedure. The shape of the metal will also have an impact on elasticity.

Some damage in a panel may be elastic deformation. Metal with ***elastic deformation*** will return to its original position if the force holding the metal out of position is removed.

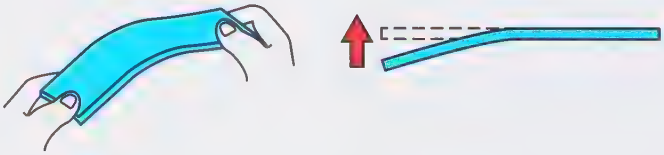


Figure 4-3. *In elastic deformation, the panel springs back to original shape once the pressure is released.*

Plasticity

Plasticity is the ability of a metal to be shaped. As stated previously, panels are shaped by bending and stretching flat sheets. A highly plastic metal can be readily shaped by bending and stretching. The grain arrangement allows the grains to elongate or compress without breaking. A highly plastic metal can be formed into complex shapes, such as fenders and quarter panels. However, a highly plastic metal is not strong. Nevertheless, strength can be designed into the part by adding bends and curves in the part. Like elasticity, plasticity varies according to metal type and annealing procedure.

The concept of plastic deformation is illustrated in **Figure 4-4**. If the applied force moves the metal beyond its yield point, it will cause a change in the grain arrangement in one small area of the metal. This permanent change in the grain arrangement is called ***plastic deformation***.

The area where the grain arrangement has changed is called a buckle or a bend. The difference between a bend and a buckle is that a ***bend*** is purposely put into the part when the part is manufactured, while a ***buckle*** is caused by impact force. Both bends and buckles are formed by the elongation of the outer grains and the compression of the inner grains. The stiffness, or hardness, of the buckle holds the metal out of place. The metal around a buckle is not damaged. It is simply forced out of position, or displaced, by the buckle.

Component Shapes

The shape of body panels and structural components will impact the way they react when damaged. Bends, body lines, and crown are often formed into panels to increase strength and improve appearance. To understand a bend, consider a flat piece of metal, such as the sheet metal blank that a car part is made from. When viewed from the side, the metal's grains are all the same size and are arranged uniformly, **Figure 4-5**. During the forming process, some areas of the sheet metal blank will be bent. A look at a cross section of the grain arrangement in the bend will reveal that the outer grains are elongated and the inner grains are compressed, **Figure 4-6**. This arrangement is seen in all bends. In mild bends, the elongation and compression are less pronounced than in severe bends. If we were to push on the metal in a bend, we would find that it is stronger than unbent metal. This is because the change in grain structure increased the strength of the metal in the bend area. The increase in strength is often called ***work hardening***. Work hardening in severe bends, such as in body lines, strengthens the panel.

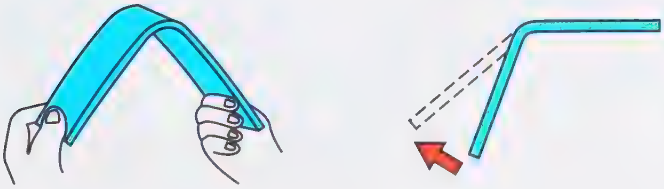


Figure 4-4. *The panel has been moved beyond the yield point, resulting in plastic deformation.*

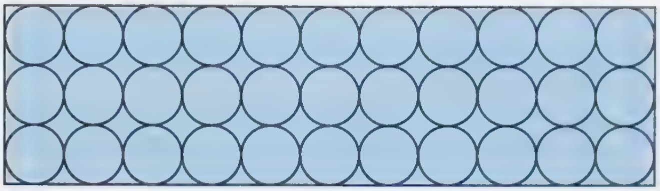


Figure 4-5. *In unworked steel, the grain pattern is uniform and the grains are the same size.*

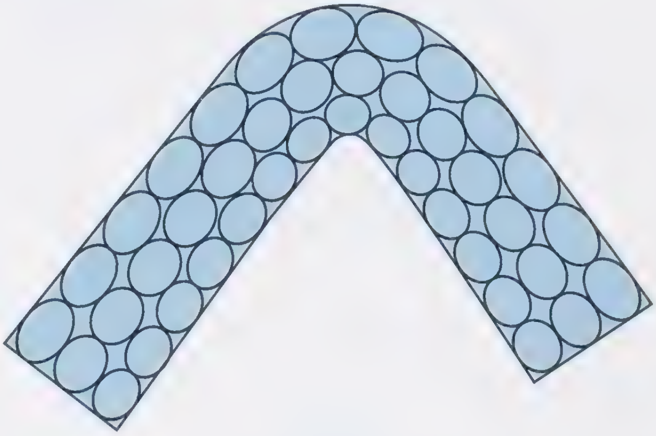


Figure 4-6. *The grains are distorted in the bend. The inner grains are compressed and the outer grains are elongated.*

A ***body line*** is a styling line in a hood, fender, or door. The body line makes the panel rigid and less likely to flex. In addition to being box structures with four bent corners, unirails—the frame rails on unibody vehicles—have many bends, or convolutions, in them that provide structural strength and energy management during a collision. Many of these unirails are made of mild steel. The vehicle designers calculate the number and location of bends to give a part the desired strength.

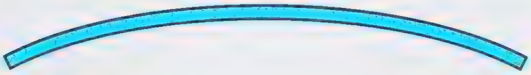
A bend that is less severe than a body line is called a crown. ***Crown*** is the curvature of a panel. Crown is found on all outer body sheet metal panels. These are the four basic types of crown:

- Low crown—Almost flat, with very little curvature. If you push in on a low-crown panel, it will flex in and pop out undamaged
- High crown—Highly curved and rigid. You cannot push the panel in with your finger. It will not flex.

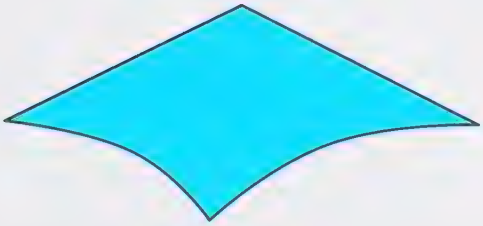
- Double crown—Curved in two directions, from top to bottom and also from side to side. Double-crown panels will not flex.
- Reverse crown—Curved in rather than out, forming a concave surface. Reverse-crown panels will not flex.

See **Figure 4-7** for examples of each of these types of crowns.

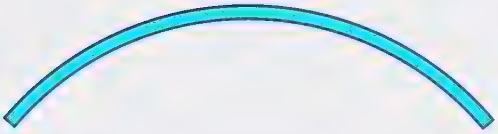
The degree of elongation and compression of the grains in a crown determines the strength of the crown. Higher crown (greater curvature) means greater strength. ***Combination crown*** means that a panel has at least two types of crown (low and high). Because most panels have combination crown, it is useful to think of crown in terms of areas rather than panels. In this way, you can identify one section of a panel as a high-crown area and another section of the panel as a low-crown area. Different types of crown require different repair methods.



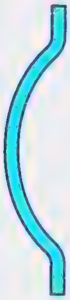
Low crown



Double crown



High crown



Reverse crown

Figure 4-7. *Low crown is nearly flat, high crown has noticeable curvature, double crown is curved in two directions, and reverse crown has a concave curve.*

In addition to bending, some body panels are formed by stretching. In a stretched area, the grains are elongated. The metal in a stretch becomes slightly longer and thinner. **Figure 4-8** shows the grain in a stretch. Stretching will increase the surface area of the stretched metal. Stretches are formed adjacent to bends when making complex shapes like double crowns.

Collision Factors

In addition to the types of metals used in vehicle construction and the way these materials are shaped, there are several collision factors that determine the amount of damage that occurs when a vehicle is involved in a collision. These factors include force, inertia, target, impact angle, surface area of contact, and vehicle height. Each of these factors will be discussed in the following sections.

Force

Force can be defined as any action between two objects that changes their relative condition as to motion or rest. In collision repair, force can be thought of as the energy exchanged when two objects collide. There are a number of ways collisions can occur. A parked vehicle can be hit by another vehicle, a vehicle can run into an unmovable object, or two vehicles moving in opposite directions can collide. In all these examples, the force or energy from one object impacts on the other object.

The force of a moving object is a product of the weight and speed of the object. If a golf ball were held one foot above a car hood and then dropped, the hood would not be damaged. However, if a baseball were

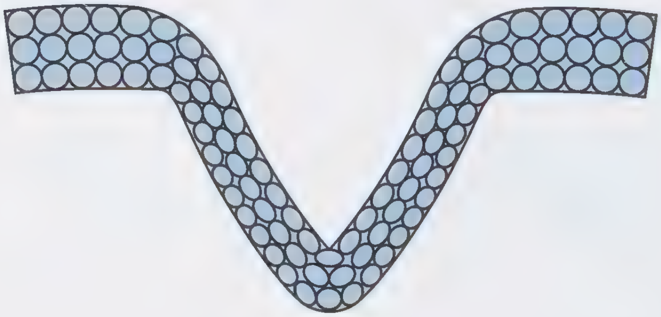


Figure 4-8. *Stretching increases the surface area of a panel. Note the elongation of the grains in the stretch.*

held one foot above the hood and dropped, the hood would be damaged. Finally, if a bowling ball were held one foot above the hood and dropped, the hood would again be damaged. Which ball would cause the most damage? Most everyone will agree that the bowling ball would do the most damage. All three balls would be moving at approximately the same speed, but the heaviest ball would have the most force and, therefore, cause the most damage. The damage would be caused by the energy from the balls rearranging the grain structure of the hood. The golf ball would not cause damage because the force of the golf ball would not exceed the yield point of the metal. The ***yield point*** is the minimum amount of force required to cause a permanent change in grain arrangement. The force of an impact must be greater than the yield point for permanent deformation to occur. The force of the baseball was great enough to rearrange the grain structure in the hood, but because there was less force caused by the baseball than the bowling ball, the grain rearrangement would not be as extensive as that caused by the bowling ball.

The other component of force is speed. If we compare two objects of the same weight with one moving twice as fast as the other, the faster-moving object has twice the force of the slower moving object. Therefore, the force that a vehicle has at the time of collision depends on the weight and the speed of the vehicle.

When force first acts on an object, the object may simply move. This is sometimes seen in a collision. When an object impacts a fender, the fender may move, or shift. Movement may not be possible because the fender is held in place by bolts, braces, and adjacent panels. If the fender cannot move and the force is greater than the yield point, deformation will result.

There are two ways force can impact on a panel, longitudinally and laterally. In **Figure 4-9**, a ***longitudinal force*** (force applied from one end) is applied to a piece of sheet metal. If the sheet metal panel is not attached to anything, the force will simply move the entire panel to the left and there will be no distortion of the panel. In **Figure 4-10**, the panel is attached, preventing any movement. A force greater than the yield point is applied at *A*. The attachment areas at *B* and *C* act as pivot points. The metal will fold between points *B* and *C*. As a fold is created, the grains in the buckle become work hardened and more resistant to further bending. A new buckle will form in the weaker metal ahead of the first buckle (between *D* and *E*). The second buckle will become work hardened. Assuming the force is removed at this point, no further damage will occur.

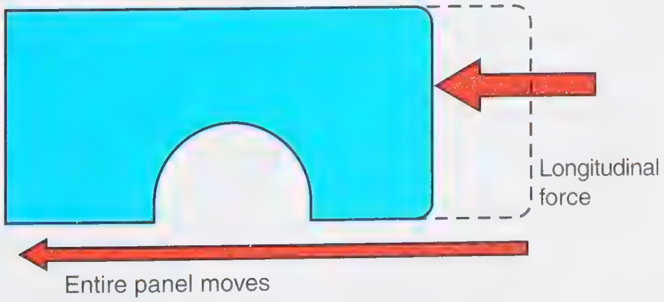


Figure 4-9. *Longitudinal force applied to the unattached fender simply moves the fender.*

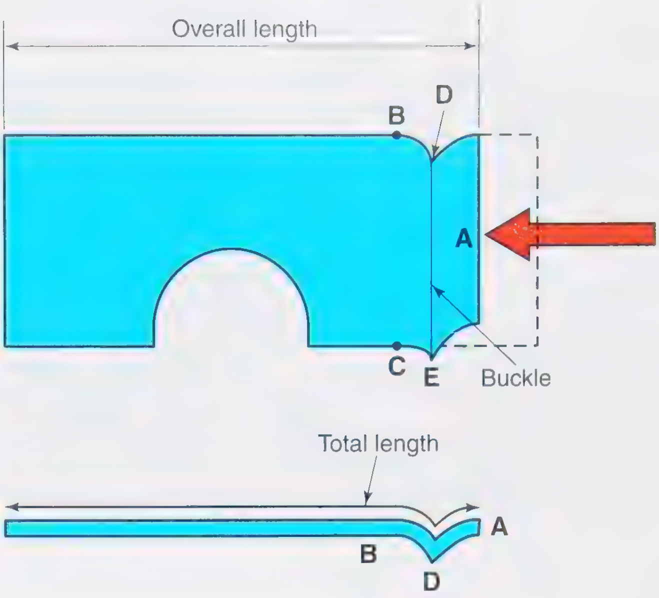


Figure 4-10. *The panel buckles first at B-C, where the attachment points act as pivot points. When the buckle at B-C resists additional movement, another buckle forms between D-E.*

An examination of the damaged panel shows that the overall length is reduced, but the surface area has not been reduced. If we were to measure the total length of the panel by measuring each fold, we would find that the total length has not changed.

To demonstrate this concept, hold a sheet of computer paper lengthwise with one hand at either end. Move one hand toward the other. Note how the paper folds. On sheet metal, these folds are called ***simple rolled buckles***. Next, simulate a body line by making a longitudinal fold in the paper. Again, hold the paper lengthwise with one hand at either end and move one hand toward the other. As you will notice, the folded paper is much stiffer than the flat sheet. Note how the distortion takes place at the fold. See **Figure 4-11**. This type of damage is called a ***collapsed-hinge buckle*** and can often be found when a fender is hit from the front. The longitudinal force causes collapsed-hinge buckling at the body line. The metal at the body line is very stiff. If a buckle forms at a body line the damage will be even stiffer.

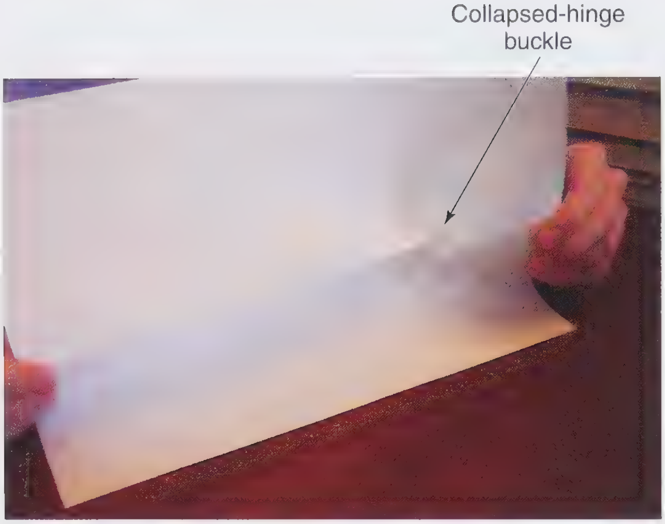


Figure 4-11. *Notice how the paper buckles at the fold.*

If the panel is not attached to anything, ***lateral force*** (force applied from the side) will simply move the panel, causing no damage. In **Figure 4-12,** a low-crown panel is attached at points *A* and *B*. In this example, the attachments allow some movement. When the force is applied at *C*, the attachments at *A* and *B* begin to move toward each other. If the force is removed before attachments *A* and *B* begin to resist movement, there will be no buckling at *C*. The "drawing in" of *A* and *B* will absorb the force at *C*, so the force will not act on the grain arrangement. If we were to raise *A* and lower *B*, the panel would return to its original shape.

Another example of lateral force is shown in **Figure 4-13**. In this example, the low-crown panel is held securely at points *A* and *B* so that the edges cannot move. A force is applied at *C*. As demonstrated in the previous example, metal is usually drawn in by lateral force. In this example, however, this cannot happen. Therefore, a buckle forms at *C* and the grains from *C* to the attachments *A* and *B* elongate, or stretch. The surface area of the metal permanently increases. This type of damage is simply called a ***dent***. There is a limit of stretch, depending on the plasticity of the sheet metal. Once the limit of stretch has been exceeded, the metal will tear.

When lateral force acts on a high-crown area, the result is different. Roll a sheet of copy paper into a cylinder and tape the ends so it will not unroll. Push in on the crowned surface. Look at the inside and outside of the cylinder. The deformation that occurs is similar to what happens when a high-crown panel is damaged by a side (lateral) impact. The force moves through the crown above and below the point of impact. Instead of stretching as a low-crown panel would, the high-crown panel collapses. As the force travels through the high crown,

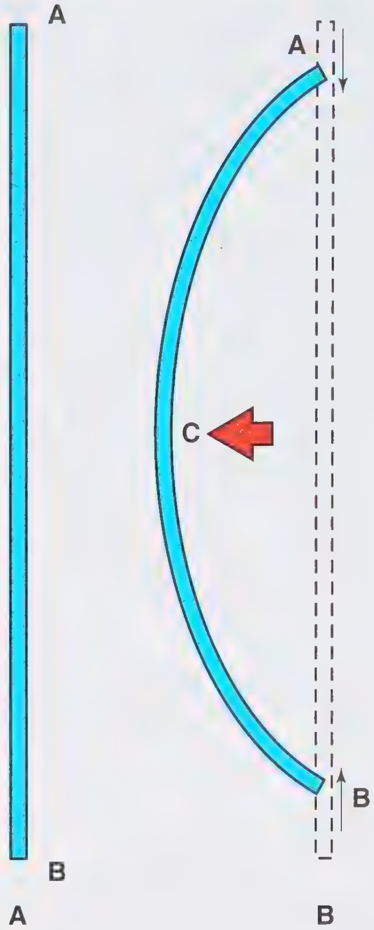


Figure 4-12. *The force at C causes points A and B to move toward each other.*

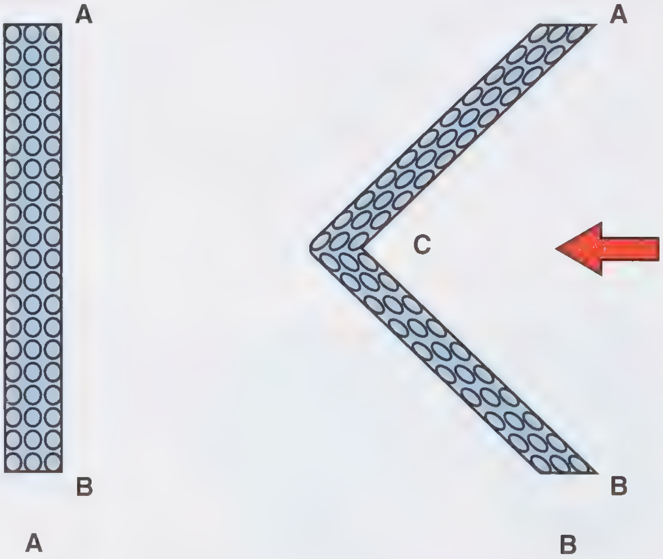


Figure 4-13. A—*Grains in a low-crown panel.* B—*When a lateral force is applied to a low-crown panel, the grains to elongate, resulting in stretch.*

buckles form. The buckles become work hardened and resistant to force. The buckles indicate how far the force traveled through the panel. This type of damage is called an ***arrowhead***. Arrowheads can also be formed by longitudinal force acting on a high-crown panel. Demonstrate this by pushing on one end of the paper cylinder. The force should form an arrowhead in the cylinder.

All collision damage found in a vehicle is caused by force from the side (lateral) or force from one end (longitudinal). If you understand these two basic ways that force can cause plastic deformation in a panel, you will have a much easier time examining and repairing damage. In summary, when a force acts on a panel it will first move the panel. If no movement is possible, the force will create buckles in the panel. Longitudinal force causes folds and buckling, lateral force causes stretching in low-crown panels and collapse and arrowheads in high-crown panels.

Inertia

If an object is not moving, energy, or force, is required to make it move. If an object is moving, force is required to make it stop. ***Inertia*** is the tendency of an object to remain at rest or to remain in motion. This means that a moving object stop or a stationary object will move only if sufficient force acts on it. Let's look at a stationary object first. Consider a large rock sitting near a road. The inertia of an object is determined by the weight of the object and the strength of any attachments holding the object in place. The inertia of the rock is simply a function of its weight—there are no attachments holding it in place. If a subcompact car moving at 10 miles per hour (16 km/h)—lightweight vehicle, slow speed, and therefore, a small force—hits the rock, the rock will not move. The force of the small car is not great enough to overcome the inertia of the rock. However, the rock would move if it were hit by a large sport-utility vehicle moving at 50 miles per hour (80 km/h). Why? The sport-utility vehicle—heavy vehicle, high speed, and therefore, a large force—has enough force to overcome the inertia of the rock. To move an object, a force greater than the inertia of the object must be applied.

As mentioned previously, inertia also influences objects that are already in motion. Unless sufficient force acts on it, a moving object will stay in motion. Some people launch boats this way. The boat is placed in the bed of a pickup truck with the tailgate down. The truck is backed toward the water at a high rate of speed. Near the water's edge, the truck's driver slams on the brakes. The truck stops at the water's edge, but the boat slides out of the bed and lands in the water. That is an example of inertia. Both the truck and the boat were moving at the same speed. The force of the brakes stopped the truck. However, the boat was not attached to the truck, so the braking force did not act on it. The boat stayed in motion until it hit the water.

For a collision example, think of a vehicle as consisting of three sections: front section, center section and rear section. On a unibody vehicle, the front section includes all parts ahead of and under the hood, the center section is everything that is between the rocker panels, and the rear section is all parts behind and under the deck lid. On a pickup truck, the three sections would be the engine compartment, the cab, and the bed.

Figure 4-14 shows a vehicle colliding with an unmovable wall. The impact event begins and ends in a split second. At the moment of impact, the front section collapses but the center and rear sections are still in motion, due to inertia. When the center section can no longer move forward, the forces at work may cause the rear end of the vehicle to rise off of the ground.

This upward deflection of the rear section may cause a buckle in the roof at a pivot point. Usually this pivot point is where the center pillar meets the roof. This damage to the roof is called ***inertia damage***. The center section may also deflect upward. The roof may move forward, causing inertia damage at the windshield pillar.

The amount of inertia a section has is determined by the weight of the section. A heavy section has more inertia than a light section and is more likely to cause inertia damage. A long section, such as a pickup truck bed, can act as a lever when it rises up during a frontal impact. The upper front portion of a pickup truck bed often hits the back of the cab during a front-end collision.

Inertia is also at work in a side impact. In **Figure 4-15**, a vehicle is sliding sideways on icy pavement and hits a tree. The inertia of the tree is great enough to resist the force of the vehicle—the tree does not move. The center section of the vehicle stops, but the front and rear sections continue moving for a split second. This causes inertia damage to the front and rear sections of the vehicle. Inertia damage is only found when a vehicle is moving with at least moderate speed and comes to an abrupt stop. A gradual stop will not cause inertia damage.

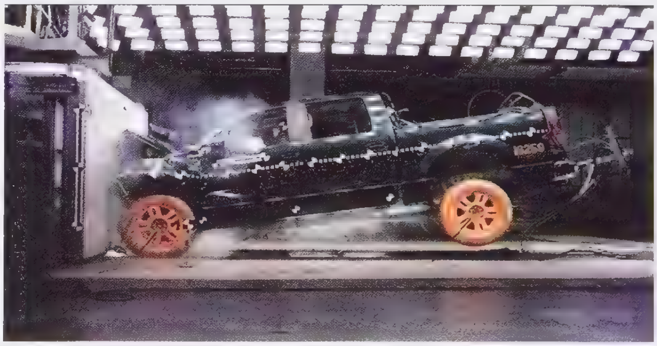


Figure 4-14. *When the front section of the vehicle has stopped moving, the rear section may rise off the ground.*

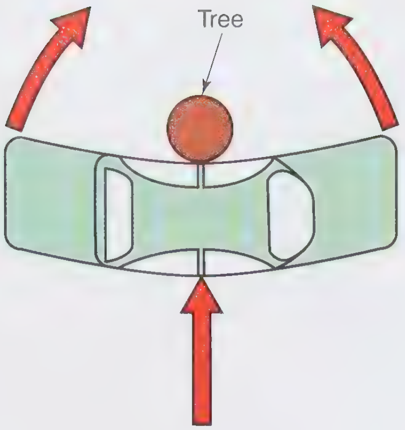


Figure 4-15. *This vehicle slid sideways into a tree. The center section of the vehicle was stopped by the tree. The end sections continued moving, resulting in inertia damage.*

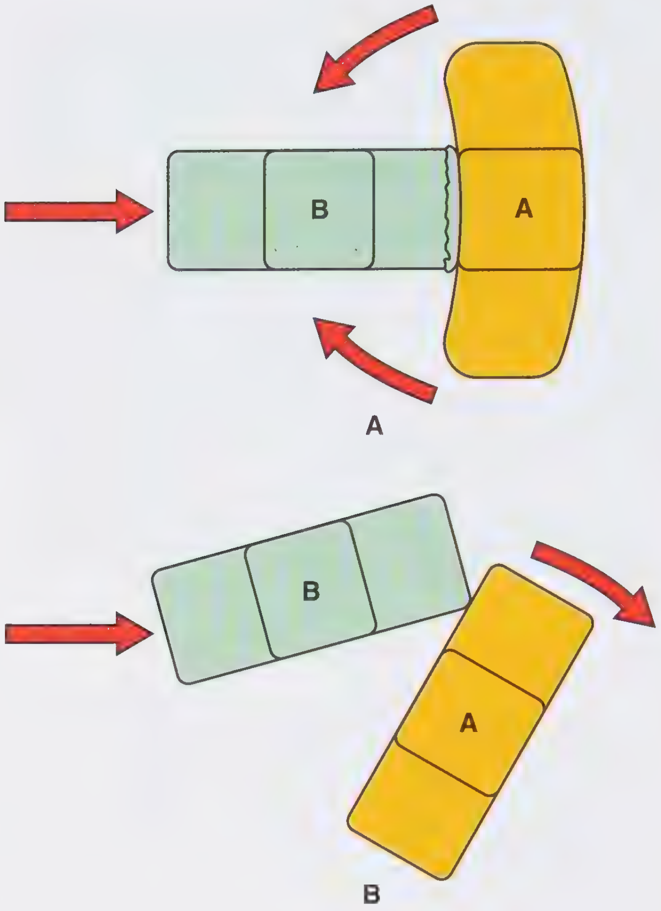


Figure 4-16. *A—If vehicle B hits vehicle A in the center section, the end sections of vehicle A will distort as it is pushed to the right. B—If vehicle B hits vehicle A on one end, vehicle A will spin.*

Target

The object a vehicle collides with is called the ***target***. The target can be at rest, or it can be in motion. Targets at rest can have enough inertia that they will not be moved by a collision. A bridge abutment is an example of an unmovable target. The weight of the abutment is so great that the impact force of any vehicle cannot overcome it. Additionally, because the abutment is solid concrete, it will not flex or give during a collision. If a vehicle were to collide with the abutment, all the force in the collision would be directed back at the vehicle. None of the force would move or distort the abutment.

A vehicle that hits a hard, unmovable target will sustain more damage than a vehicle that hits a movable target. When a vehicle hits a movable target, some of the collision force is used to overcome the inertia of the target, setting the target in motion. This is energy that will not be directed back at the vehicle. Some examples of targets that can be set in motion include other vehicles, fence posts, guardrails, and small trees. Some targets may also be in motion. If two vehicles collide head on, the force of the collision is the sum of the forces of each vehicle. If a vehicle crashes into a target that is soft, some of the collision energy will be used to deform the target. Therefore, not all the collision energy will be directed back at the vehicle.

Impact Angle

The next collision factor to be considered is the ***impact angle***. **Figure 4-16A** shows an accident that occurred after vehicle A ran a red light. The driver of vehicle B attempted to stop and steer away from vehicle A. The attempt was unsuccessful and a crash resulted. Vehicle B impacted near the center of vehicle A. The force from vehicle B distorted both vehicles and pushed vehicle A sideways. The energy distribution during the collision would be different if vehicle B hit vehicle A away from the center. **Figure 4-16B** shows vehicle B impacting near the front of vehicle A. Some of the force is used to make vehicle A spin. Therefore, less force is used to distort the vehicles. From this, you can see that if the impact takes place at the vehicle's center, the damage will be greater than if the impact takes place away from the center.

Surface Area of Impact

The next collision factor is the ***surface area of impact***. If the surface area of impact is large, the collision force is spread out over a large area. If the surface area of

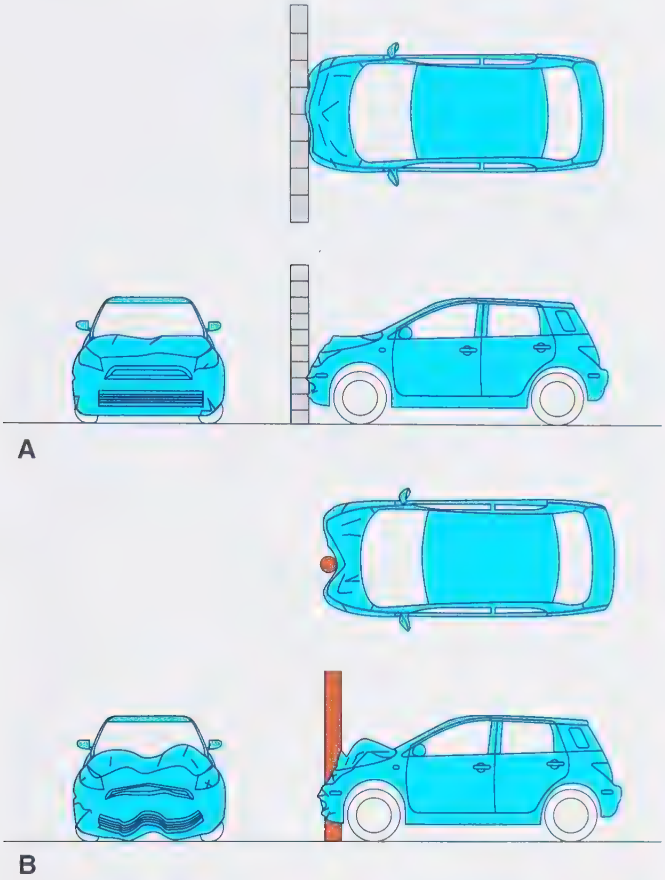


Figure 4-17. *A—If the impact force is spread over a large area. Damage is confined to the front 1' of the vehicle. B—When the impact force is concentrated in a small area, the damage extends more than 1' into the engine compartment.*

impact is small, the force is concentrated in a small area. **Figure 4-17** shows how this works. The only variable in this example is the surface area of impact. The vehicles are the same weight, they are moving at the same speed, and the targets do not move or give. In **Figure 4-17A**, the entire front of the vehicle sustains damage. The damage does not extend more than about one foot into the engine compartment. In **Figure 4-17B**, there is a smaller area of impact but the damage extends much farther into the engine compartment. In a collision, force concentrated in a small area will tend to cause deeper damage than force spread out over a larger area.

Vehicle Height

The last collision factor that must be considered is ***vehicle height***. When the front of a vehicle collides with a target, it is the front bumper that first contacts the target. The bumpers on all vehicles are bolted to the frame or unirails. The frame or unirails are the parts of the vehicle most resistant to impact.

Ideally, the bumpers of the vehicles involved in a collision would match in height. This would give the passengers the most protection. However, bumper heights are not uniform. Compare the bumper heights of the vehicles shown in **Figure 4-18**. If the car were to crash into the pickup truck, the car's hood, not the bumper, would hit the rear bumper of the truck. The hood area of the car is not as strong as its bumper. Because this hood area is relatively soft, the car would suffer more damage than it would have if the impact had taken place on the bumper.

As another example, consider a pickup truck that crashes into the side of a small car. The rocker panel of the car is strong, but the truck's bumper is higher than the rocker panel. The truck's bumper will push the car's center pillar and doors inward. This is because the car's center pillar and doors are not as strong as the bumper. In this example, passengers could be injured.

Damage

As discussed in the previous section, there are several factors that play a part in the amount of damage that occurs in a crash. In the following sections, the types of damage that occur in full-frame and unibody vehicles will be discussed. As you read these sections, remember that because all parts of the vehicle are connected, damage in one area can have an effect on other areas of the vehicle, even an area far from the point of impact.

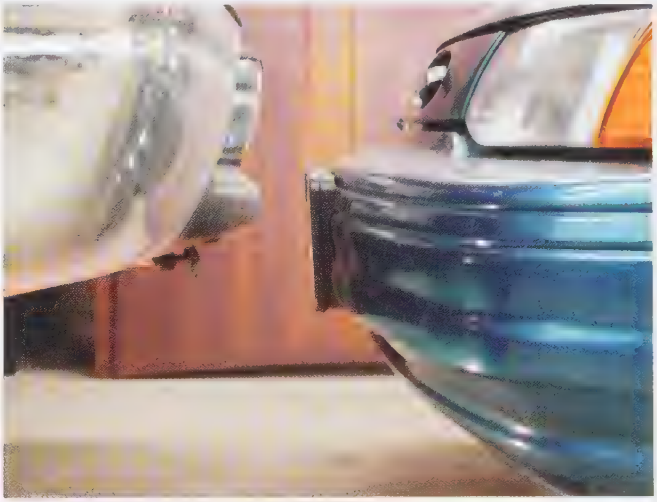


Figure 4-18. *The truck bumper and car bumper are not the same height.*

Direct and Indirect Damage

Damage that occurs at the point of contact during a collision is called ***direct damage***. **Figure 4-19** shows a damaged high-crown panel. This damage was caused by the bumper of another vehicle hitting the molding. The area of direct damage is small. However, the panel has collapsed, with buckles extending away from the area of direct contact. All the damage except for the damage on the molding is indirect damage. ***Indirect damage*** occurs away from the point of impact and is a result of the direct damage. In the indirect damage, arrowheads and low areas can be seen. The arrowheads are located at the furthest extent of the damage. The arrowheads consist of two ridges, or high areas, converging to a point. This damage was caused by the lateral force of the bumper.

In a high-crown panel, lateral force causes a compression of the grains until the panel can no longer collapse. This compression of the grains is called ***upset***. The compression of the grains is most noticeable at the point of the arrowhead and causes a reduction in surface area. The point of the arrowhead is sharp and the paint at the point is often chipped. This paint damage is also indirect damage. The paint chips off at the upset area because the paint cannot shrink in surface area the way metal can.

Each arrowhead consists of two types of buckles. The upset area at the point of the arrowhead is a collapsed rolled buckle. The two high ridges extending away from this point are simple rolled buckles. The metal between the ridges is low, but it is not buckled. It is simply displaced. Remember that metal can be held out of position but otherwise be undamaged. If the ridges holding the displaced metal out of position are released correctly, the displaced metal will move back into position with minimal effort.

If enough force is applied to a high-crown panel, the crown will collapse. The panel then reacts like a low-crown panel. Force beyond the point of collapse causes stretching and tearing.

The vehicle in **Figure 4-20** was hit longitudinally on the rear bumper. When the vehicle was rear ended, the frame rail collapsed from the force on the rear bumper. Some of the force was transferred to the quarter panel. The force traveled through the panel, and the panel moved forward somewhat. Also, the collision force caused a rearrangement of the grain structure in the panel. Remember that longitudinal force on a flat panel causes folds at the pivot points. A pivot point is a strong area in the panel. In this quarter panel, the strong areas of the panel are the body line, the area behind the wheel opening, and the internal brace. These are areas where the folding occurred. These folds are collapsed hinge buckles. Because the impact was on the bumper and not on the quarter panel, all the damage to the quarter panel is indirect damage. If you were to feel the buckles, you would find that they are smooth. The displaced metal in the damaged area is held out of position by the buckles in the quarter panel and the collapsed frame rail.

Figure 4-21 shows a simple dent in a low-crown panel. All the damage is direct damage. The metal in the low-crown area is more elastic than that in a high-crown area. If you were to feel this damage, you would find only a low spot. If you use a straightedge around the edge of the dent, you may find a slight ridge. If the dent is deep enough, the metal in the dent will be stretched.

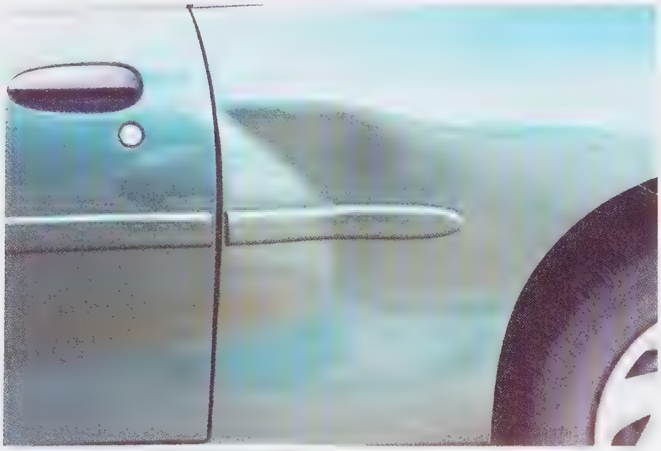


Figure 4-19. *A bumper striking the molding caused this damage. Notice the door gap is wider in the center of the door than it is at the top and bottom edges.*

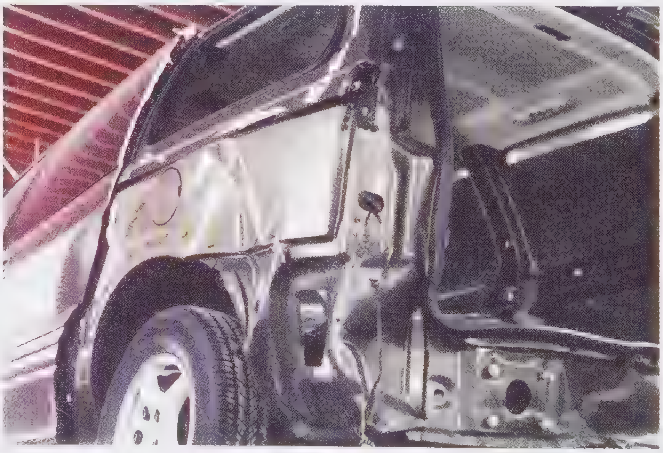


Figure 4-20. *The damage on this quarter panel is indirect. The vehicle was hit on the rear bumper.*

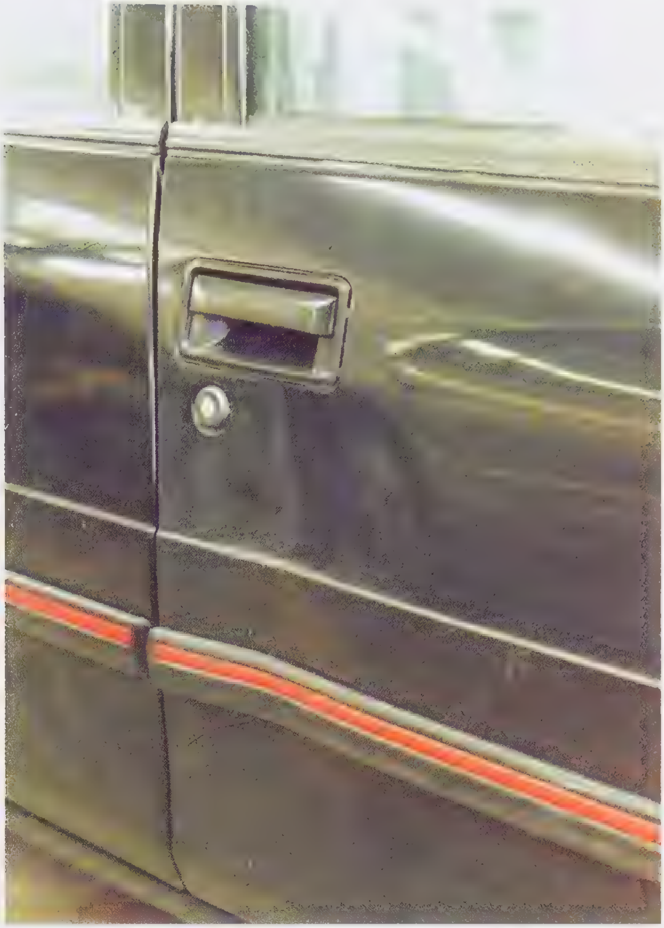


Figure 4-21. *This dent in a low-crown panel is all direct damage.*

Bend-versus-Kink Rule

The ***bend-versus-kink rule*** states that damaged high-strength steel parts can be repaired if they are bent but must be replaced if they are kinked. When high-strength steel is kinked, the grain structure may be changed enough to be permanently weakened by microscopic cracks. A ***kink*** has a buckle that is greater than 90° in a short area. The metal is folded so tightly that the radius of the buckle is 1/8" (3 mm) or less. The metal may be cracked in the tightest part of the kink. Even after repair, the weakened high-strength steel cannot properly support the weight of the vehicle or protect the passengers during a collision. Therefore, a kinked high-strength steel panel must be replaced.

NOTE

The term *bend* is often used in the collision repair industry when referring to a buckle. For example, the bend-versus-kink rule actually deals with differences between buckles and kinks.

The grain structure in slightly damaged high-strength steel does not change enough to produce the microscopic cracks. Slightly damaged high-strength steel is not weakened. Slightly damaged high-strength steel has a buckle that is not tightly folded and is less than 90°. A buckle is smooth, while a kink is severely folded.

Many full-frame and unibody vehicles are made from a combination of mild steel and high-strength steel. A technician cannot tell mild steel from high-strength steel. Because it is so important that high-strength steel be replaced if it is kinked, and because mild steel cannot be distinguished from high-strength steel, I-CAR recommends that all the steel in a vehicle be treated as high-strength steel. Based on this recommendation, all-load bearing and structural parts of a damaged vehicle should be replaced if kinked. Only buckles should be straightened.

However, this rule does not necessarily apply to aluminum structural parts. Check the manufacturer's recommendations to determine what type of damage can be repaired and what type requires part replacement.

Full-Frame Damage

A full-frame vehicle, such as a pickup truck, has a frame made of hot-rolled steel. The frame members can be U-shaped or boxed. Four-wheel-drive vehicles often have a frame made entirely of boxed members. Two-wheel drive vehicles can have a frame made entirely of U-shaped members or a frame consisting primarily of U-shaped members with some boxed members for extra reinforcement. The two sides of the frame are called the frame rails. The frame rails are connected by bolted, riveted, or welded cross members. When viewed from the top, some frame rails are stepped in near the front suspension mountings as shown in **Figure 4-22**. When viewed from the side, all frame rails have some type of arch. See **Figure 4-23**.

Frame rails and cross members are strong. The thickness and weight of the frame make it resistant to force. When impact forces greater than this resistance act on the frame, the frame rails tend to transfer these forces through the vehicle. The frame will usually distort in the area of a pivot point. Most full-frame vehicles are not designed to collapse and absorb impact forces. A unibody vehicle, on the other hand, is designed to collapse so the vehicle absorbs the impact forces, protecting the passengers. Some full frames have notches or crush zones that absorb impact forces.

Front Impact

The bumper on a full-frame vehicle is bolted directly to the frame, so the frame is generally one of the first items affected in the event of a collision. For example, consider a pickup truck that has taken a hit on both rails. If the impact force is greater than the resistance of the frame, the frame will be damaged. The impact force will

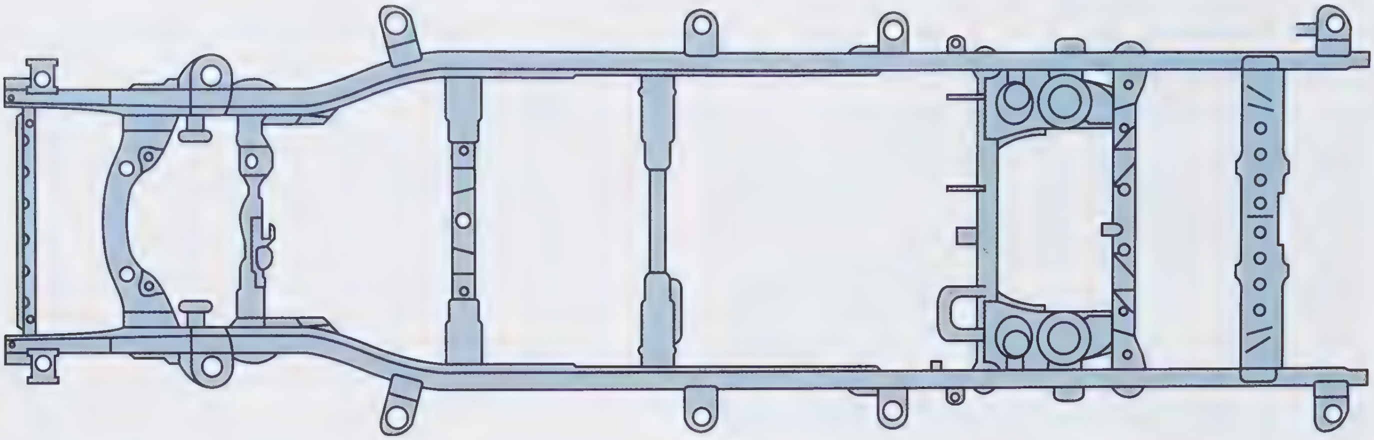


Figure 4-22. *The step-in area is near the suspension mounting area. The frame is slightly narrower in the front. (Toyota)*

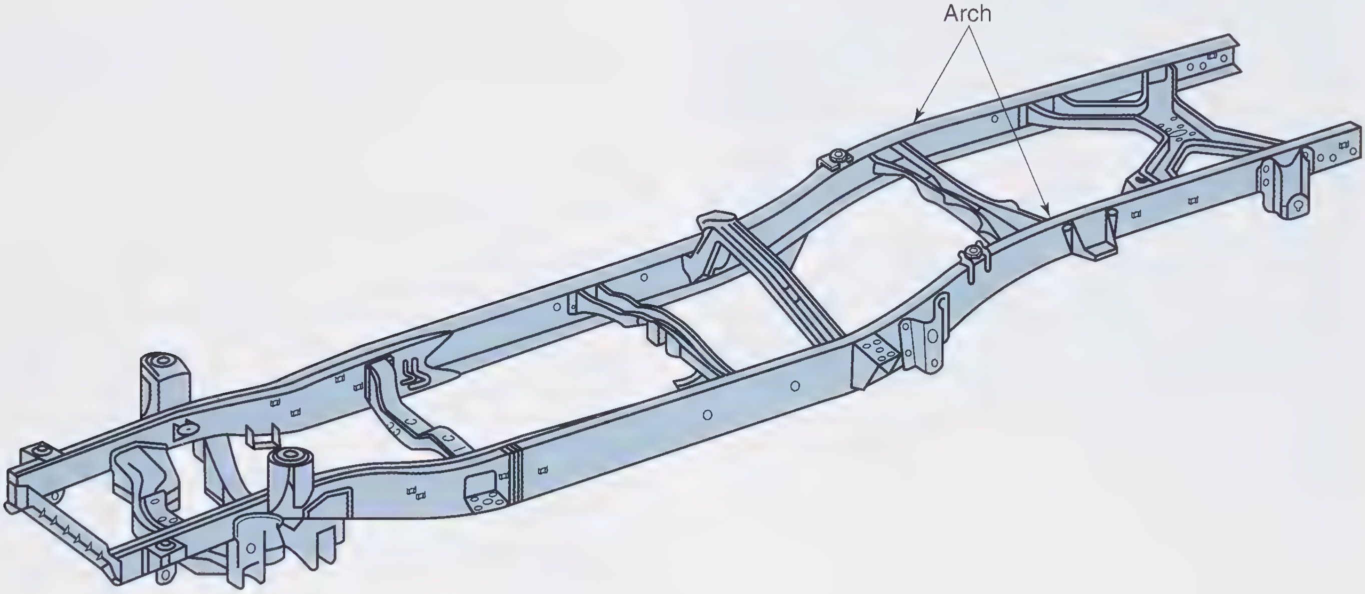


Figure 4-23. *This frame has arches at the front and rear suspension mounting areas.*

travel through the frame until the force is dissipated. Depending on the frame design, the force may cause the frame rails to move up or down. In one type of truck, the frame rails move upward. If the impact force is great enough, the upward movement of the frame can cause the engine to hit the cowl.

The cross members or frame step-in may act as a pivot point for the impact force. The impact force may cause distortion or buckling just ahead of the pivot point. See **Figure 4-24**.

The damage caused in this collision would be a change in frame height and length. The change in frame height is called ***kickup*** when the frame moves up and ***sag*** when the frame moves down. The change in frame length is called ***mash***.

If the impact is between the frame rails as shown in **Figure 4-25**, the frame rails move toward each other.

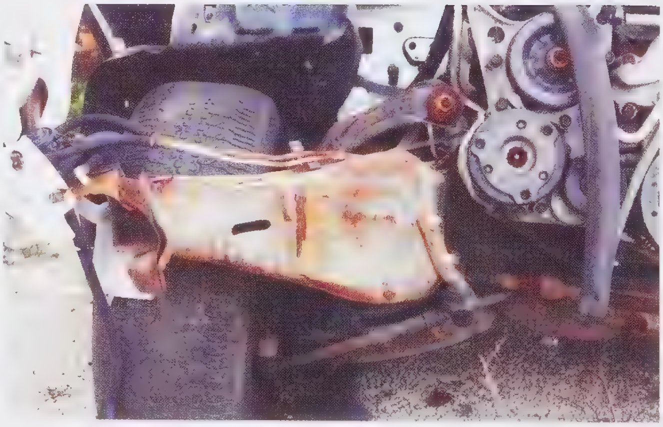


Figure 4-24. *An impact on the left front of the vehicle caused this buckle in the right frame rail. The engine cross member served as a pivot point.*

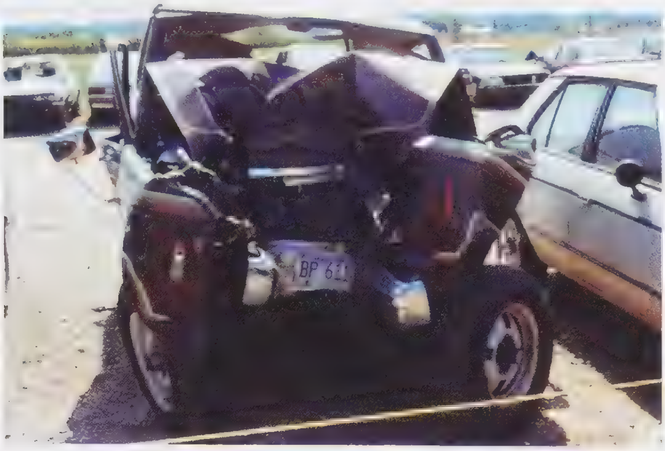


Figure 4-25. *This full-frame vehicle has sidesway. Note the rails have moved toward each other.*

The lateral movement of the rails is called ***sidesway***. If the impact is on one rail, only the impacted rail will move back. The other rail does not move back, but it may move toward the damaged rail. After this type of impact, the cross members and rails no longer meet at right angles. See **Figure 4-26**. This type of damage is called ***diamond*** because the frame rails and cross members in the center section of the vehicle no longer form a rectangle. The distorted area is shaped like a diamond.

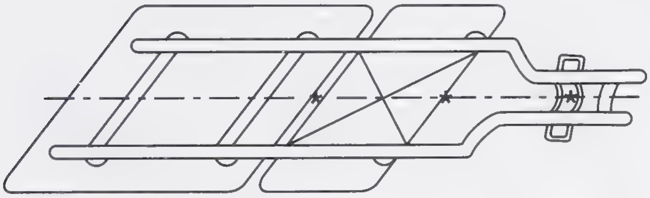


Figure 4-26. *Diamond damage is present when the center section of the vehicle is not square.*

As any of these front impacts are taking place, inertia can be involved. Again, consider a truck involved in a front impact. If the target is solid and unyielding so the truck stops in an instant, the bed could deflect upward, causing dents in the back of the cab. If the inertia is great enough, the frame will buckle. The buckle in the frame will usually be found under the cab. This type of damage may be deceiving. It may look as if the truck is bent down under the cab. Actually, the rear suspension mount is distorted upward. This makes the center of the vehicle sit closer to the ground. The same is true in a frontal impact that distorts the front suspension mounts upward. The front suspension is higher than normal, again causing the center of the truck to sit closer to the ground. If the frame rails under the cab are not level with each other, the damage is called ***twist***. A severe front impact can cause twist in the frame.

As a frame rail or cross member moves during a collision, attached parts may also be damaged. Parts that can be damaged by a front impact include the front axle assembly, front suspension, exhaust manifold, starter, transfer case, transmission, body or cab mounts, floor, and cowl. If a door does not fit properly, you should suspect cowl damage.

Side Impact

A side impact at the front of a full-frame vehicle may cause one or both frame rails to move. This type of damage is sidesway. If the frame is impacted as shown in **Figure 4-27**, part of the impact force will cause a buckle in the right frame rail. The rest of the impact force will be transferred by the front cross member to the left frame rail. If the cross member is weak and the left frame rail has enough strength to resist the force, the cross member will buckle and the left frame rail will not be damaged. If the left frame rail cannot resist the force, the cross member and both frame rails will be damaged.

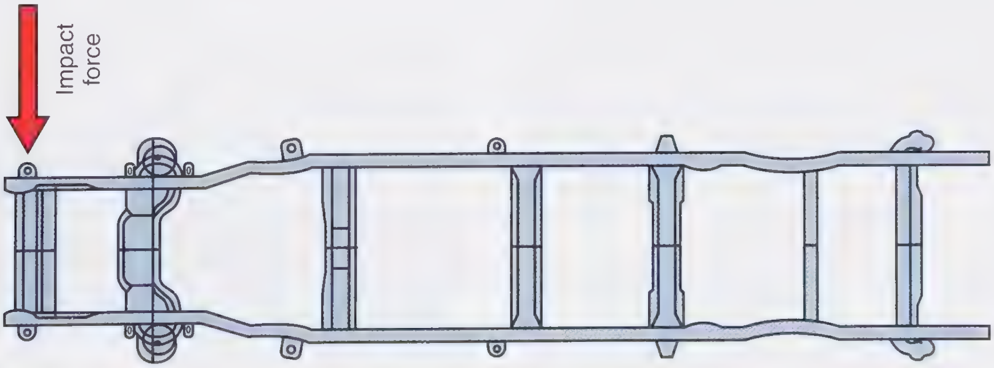


Figure 4-27. *The impact force will be transferred from the right frame rail, through the cross member, and to the left frame rail. Both rails have moved.*

Figure 4-28 shows portions of a frame that has sidesway on both U-shaped frame rails. The impact point was the same as that shown in Figure 4-27. Notice the buckles on the flanges of the rail that was directly damaged, **Figure 4-28A**. The rail that was indirectly damaged appears to have suffered more damage. The flanges of the indirectly damaged rail were stretched to the breaking point. See **Figure 4-28B**. Note that the engine cross member acted as a pivot point.

If the impact is not on a cross member the collision force will not be transferred as readily to the non-impact frame rail. The cross members may act as pivot points. The wheelbase may shorten on the impact side. If enough inertia is involved, the vehicle may take on the shape of a banana. See **Figure 4-29**.

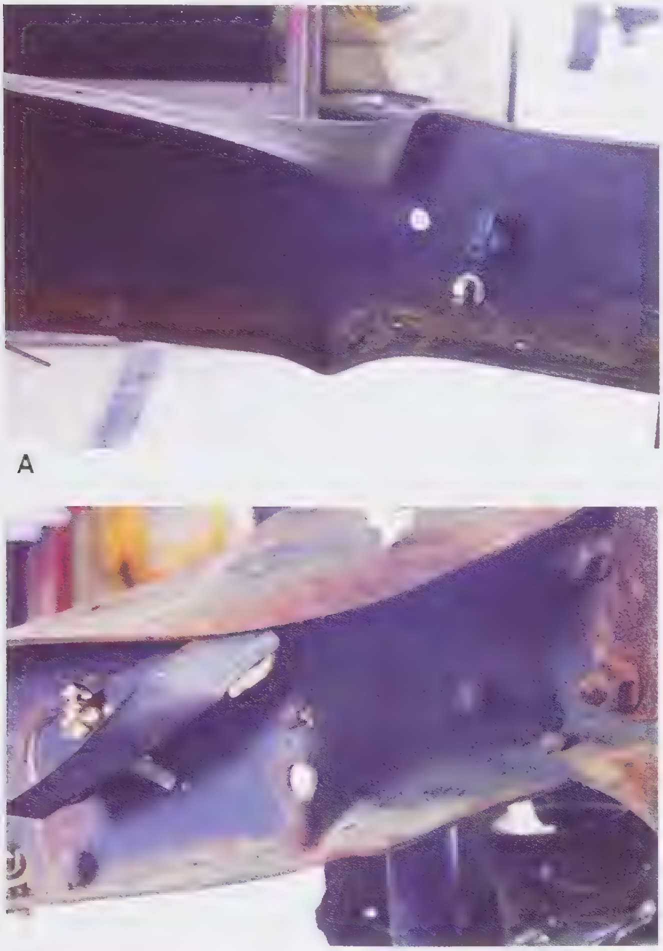


Figure 4-28. *A—In this view, the impact force would be moving toward you. This directly damaged U-shaped frame collapsed in this way from the lateral force. B—In this view of the opposite frame rail, the impact force would be moving away from you. The indirectly damaged U-shaped frame rail stretched from the lateral force.*

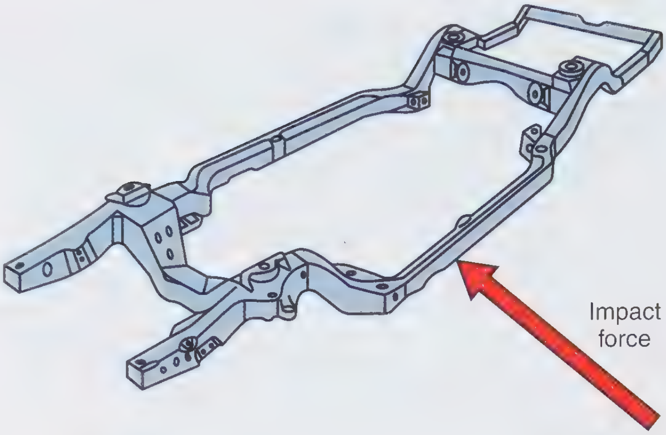


Figure 4-29. *If the impact is not on a cross member, the cross members may act as pivot points and the wheelbase may shorten on the impact side. (Chief)*

Rear Impact

The results of a rear impact are similar to those caused by a front impact. With enough impact force, the frame will distort up or down in the arched areas. Buckling may be found in the arched areas or at the cross members. **Figure 4-30** shows a truck that was rear ended. One side of the vehicle is higher than normal. The arched area of the frame rail on the impact side has been shortened by mash damage. The mashed rail holds the ends of the leaf spring closer together. This shorter spring length causes a greater-than-normal arch in the spring. The overly arched spring causes the impact side of the vehicle to sit higher off the ground. Mash is most likely to occur in an arched area of a frame. This type of damage is not often found on pickup trucks that have a straight frame rather than an arched frame in the bed area.

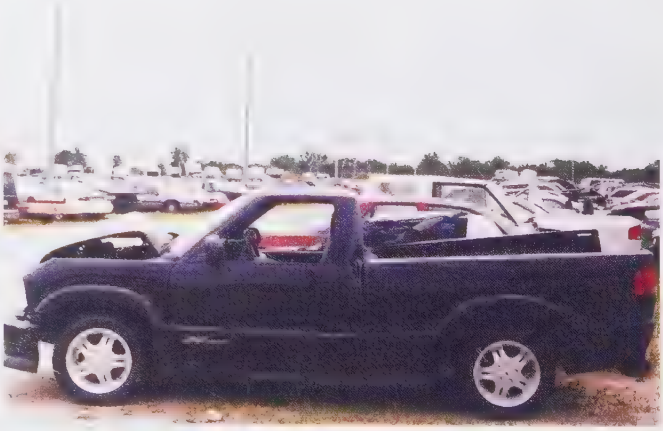


Figure 4-30. *Mash in the arched area caused the spring to have greater-than-normal arch, causing the impact side of the vehicle to sit higher off of the ground.*

Rollover

The amount of damage caused by a rollover can vary greatly. Some variables in a rollover include the surface that the vehicle lands on and the degree of rollover. Soft snow absorbs force, while hard rock deflects the force back at the vehicle. If the vehicle is airborne and lands on its roof, it will often suffer enough damage that it will not be repairable. If the vehicle ends up on its roof from a side impact, the damage may not be as severe. **Figure 4-31** shows a truck that has rollover damage.

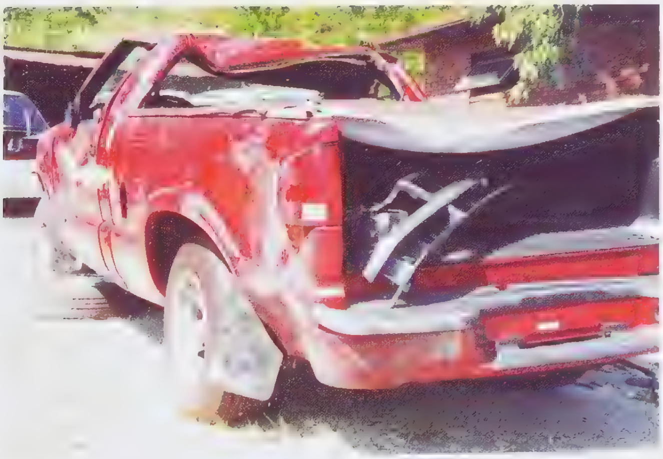


Figure 4-31. *This truck rolled over. Notice the extensive damage to the cab.*

Unibody Damage

The terms used to describe unibody damage are the same as those used to describe full frame damage. Unibody damage often involves distortion of the unirails. A shortening in the length of a unirail is called mash; a change in height is called sag (down) or kickup (up); movement of one or both unirails to the left or right is sidesway; and if the rocker panels are not level with each other, the damage is called twist. Diamond damage can also occur in a unibody vehicle. In this type of damage, the center section of the vehicle is not square, due to an impact on a front or rear corner. A unibody vehicle with diamond damage is extensively distorted and is not likely to be repaired.

To help you envision unirail damage, construct a model as shown in **Figure 4-32**. Begin by making a fold across the width of the paper. This fold represents a convolution or reinforcement in a unirail. Then, fold the paper lengthwise as shown and tape it to make a box structure. Push the ends of the box together to simulate longitudinal force on a unirail. Note that the paper box distorts in the area of the first fold (convolution or reinforcement). The paper box does not mash uniformly. Instead, it is shorter on one side than the other. The shortening on one side causes the box to deflect up, down, or sideways. The box is no longer straight.

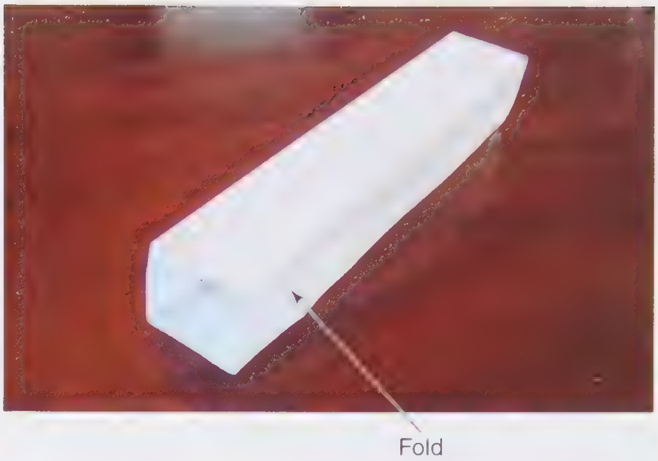


Figure 4-32. *Fold the paper as shown to represent a unirail. Note that the first fold should be in the "up" position for this model to work properly.*

This is similar to what happens when longitudinal force is applied to a unirail. The force of the impact moves through the unirail until it hits a convolution. The convolution acts as a pivot point. Buckling takes place at the pivot point. Any remaining force travels to the next convolution and buckling again occurs. As force travels through the unirail, each convolution distorts as it absorbs energy. In this way, the collision force is kept away from the passengers, if possible. If the force is great enough, distortion can take place in the passenger compartment.

Look inside the paper box. One side of the box is collapsed and the other side is stretched. This type of damage can also be found if lateral force is applied to a unirail. A side impact will bend a unirail at a pivot point. This type of damage is obvious, but unibodies can also have subtle damage. If a component has moved during the collision, either from collision force or inertia, there will be clues. Some of these clues include misaligned panels, broken spot welds, cracked paint, split sealer, open seams, buckles, and bulges.

WORKING SMART

You should always consider the bend-versus-kink rule when assessing unibody damage. If a bent unirail is straightened properly, the repaired rail will be as strong as an undamaged rail. However, if the impact force is great enough to cause a kink, the damaged rail is not repairable, even if it is not high-strength steel.

Front Impact

Figure 4-33 shows how longitudinal force from a front impact moves through a unibody. The unibody is designed to absorb collision forces. The unirails are made with convolutions. Some impact force is absorbed at each convolution. In this way, a unibody gradually absorbs collision force. **Figure 4-34** shows a collapsed lower front unirail.

When examining a unibody vehicle for front impact damage, start at the rear and look for panel misalignment. If collision force reached the passenger compartment, look for wrinkles in the floor. To find the wrinkles, either remove the carpet from inside the vehicle or raise the vehicle on a lift and look at the floor from the outside. If the cowl has been moved back, the front door will not fit properly. The door may drop when it is opened, or the gaps around the door may be tapered when the door is shut. **Figure 4-35** shows a unibody vehicle that has

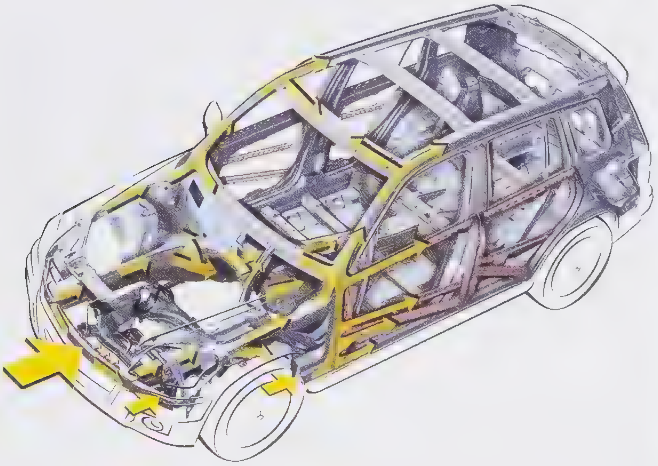


Figure 4-33. *The unibody is designed to absorb impact force by collapsing. (Mercedes-Benz)*

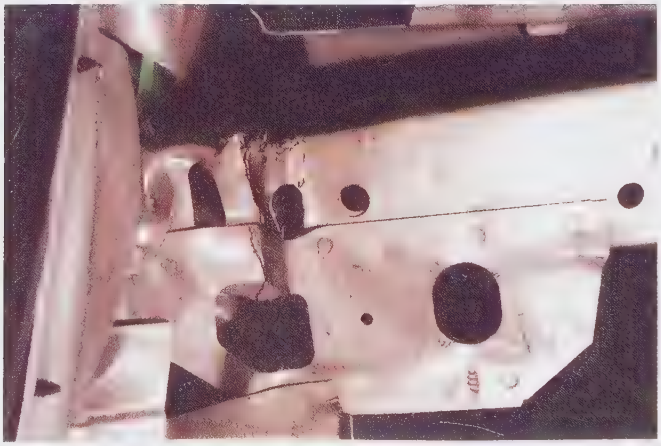


Figure 4-34. *Impact force on the front bumper caused this lower front unirail to collapse.*

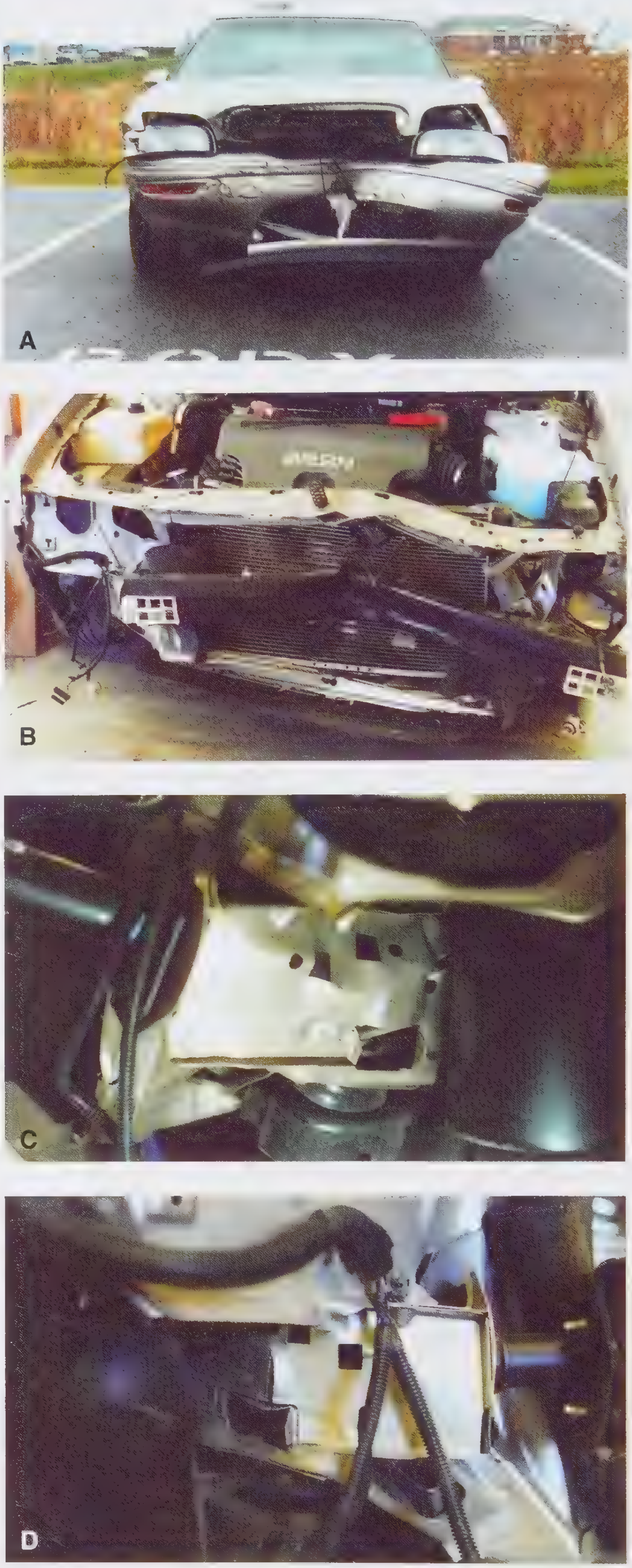


Figure 4-35. *A—This unibody vehicle was hit in the front. B—Removal of the front bumper exposes damage to both lower front unirails. C—Right front unirail. D—Left front unirail.*

been hit on the bumper. Both unirails were affected. The unirails have moved to the side, causing sidesway at a pivot point. The unirails are designed to move in this way from a front hit.

A high frontal impact is shown in **Figure 4-36**. The lower unirail is undamaged, but the radiator support, apron, and upper unirail are buckled. The damage does not extend to the cowl. **Figure 4-37** shows a unibody with extensive impact damage that extends into the passenger compartment.

Side Impact

Figure 4-38 shows a unibody hit on the side of the front fender. Both lower unirails have moved. Interestingly, the rail on the side opposite the impact has the most damage. A side hit at the cowl is shown in **Figure 4-39**. This type of hit causes a lateral force on the rocker panel, door, fender, and unirails, resulting in a longitudinal force on the cowl. Notice how the door protrudes out at the top. This indicates that the cowl is out of alignment. The windshield was cracked by the movement of the windshield pillar. You should suspect damage along the entire width of the cowl.

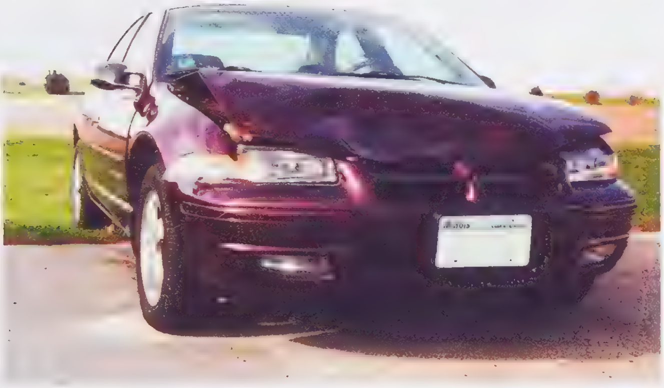


Figure 4-36. *This car hit the rear bumper of a truck. All the damage is above the lower front unirails.*

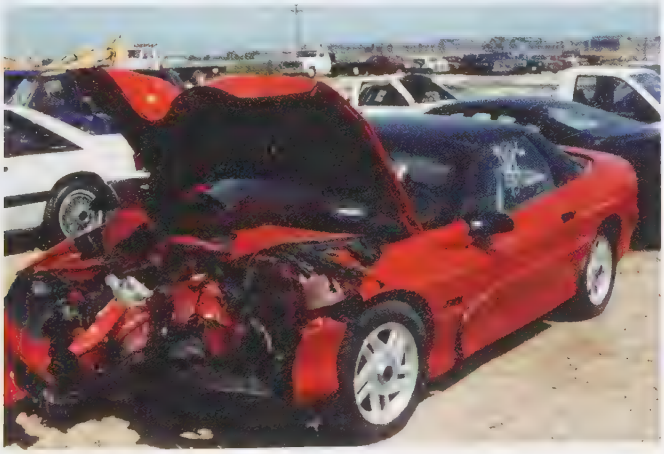


Figure 4-37. *The damage to this vehicle extends into the passenger compartment.*

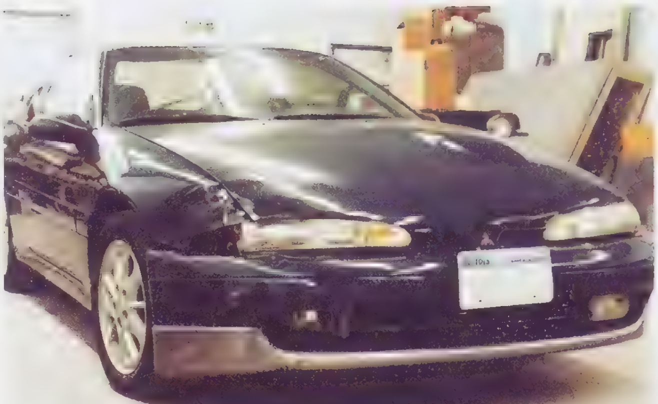


Figure 4-38. *This unibody vehicle was hit on right front. The right unirail was pushed upward. Both right and left unirails were pushed to the left. The damage to the left unirail was more extensive than the damage to the right unirail.*

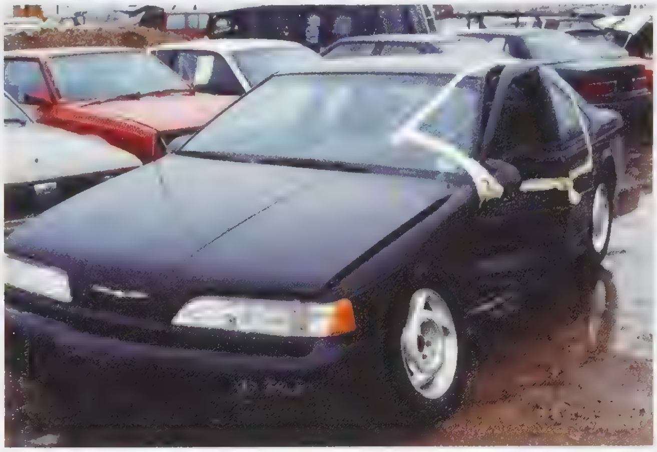


Figure 4-39. *This vehicle suffered a lateral hit at the cowl. This type of damage can be difficult to repair.*

Figure 4-40 shows a side impact at the center pillar. The vehicle has sidesway damage. Notice how the movement of the center pillar pulled down on the roof. The rocker panel and floor are buckled.

Rear Impact

Figure 4-41 shows a unibody vehicle that was struck on the rear bumper. The impact force was spread out over the two rear unirails, causing them to collapse. The rear body panel, the trunk floor, and both quarter

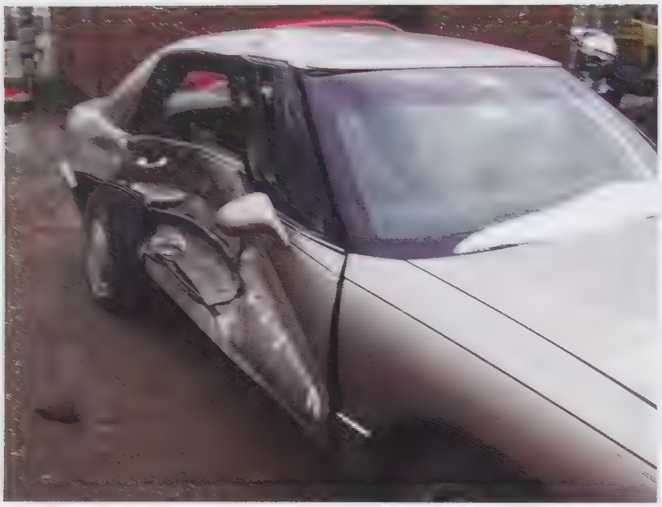


Figure 4-40. *This unibody vehicle was hit hard in the center pillar. The damage extends into the roof, rocker panel, and floor.*

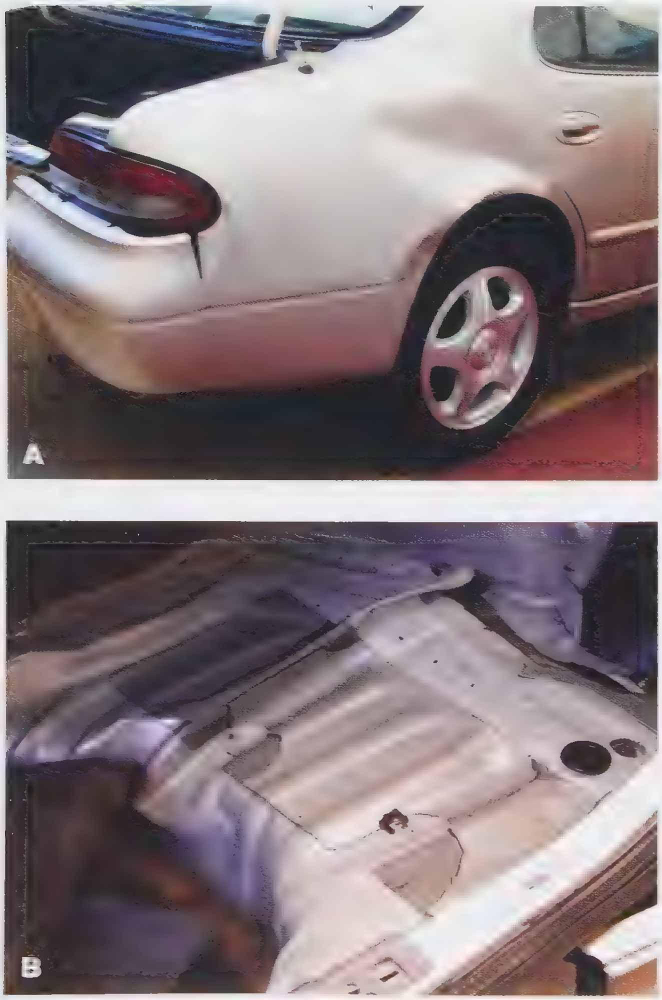


Figure 4-41. *A—This unibody vehicle was hit hard in the rear. Both rear unirails are collapsed and the quarter panels are buckled. B—The trunk floor was also damaged.*

panels are buckled. The gap at the rear of the doors is tight. This vehicle has both mash and sidesway damage.

Rollover

As in a full-frame rollover, the amount of damage sustained by a unibody rollover depends on the surface the vehicle lands on and the type of rollover. A rollover can cause damage to the lower frame rails. Twist damage can also result. **Figure 4-42** shows rollover damage on a unibody vehicle.

Summary

- The properties of the metals used in a vehicle will affect the amount of damage that occurs when the vehicle is involved in a collision.
- Different types of metals have different grain patterns. Grains are formed by the crystalline pattern of the metal and alloy molecules.
- Metal with elastic deformation will return to its original position if the force holding the metal out of position is removed.
- If an applied force moves metal beyond its yield point, it will cause a change in the grain arrangement in one small area of the metal. This permanent change in the grain arrangement is called plastic deformation.
- A bend is purposely put into the part when the part is manufactured, while a buckle is caused by impact force.

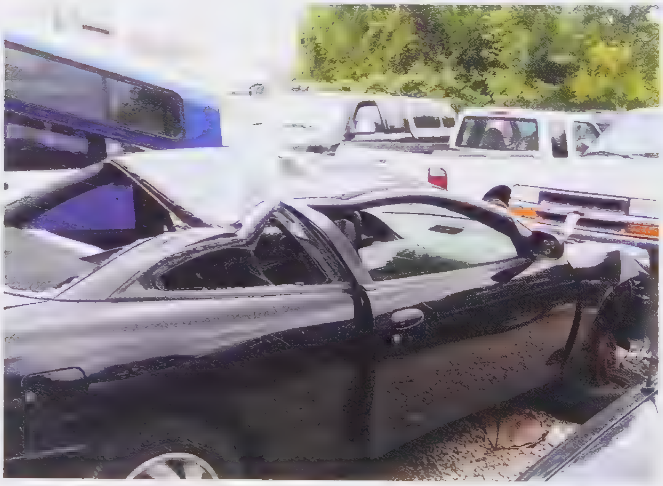


Figure 4-42. *This unibody vehicle became airborne and landed hard on its roof.*

- A bodyline is a styling line in a hood, fender, or door.
- Crown is the curvature of a panel. Crown is found on all outer body sheet metal panels.
- Force can be defined as any action between two objects that changes their relative condition as to motion or rest.
- Yield point is the minimum amount of force required to cause a permanent change in grain arrangement.
- Longitudinal force is force applied from one end of a panel.
- Lateral force is force applied from the side of a panel.
- Inertia is the tendency of an object to remain at rest or to remain in motion.
- The object that a vehicle collides with is called the target.
- If an impact takes place at a vehicle's center, the damage will be greater than if the impact takes place away from the center.
- If the surface area of impact is large, the collision force will be spread out over a large area. If the surface area of impact is small, the collision force will be concentrated in a small area.
- Damage that occurs at the point of contact during a collision is called direct damage. Indirect damage occurs away from the point of impact and is a result of the direct damage.
- The bend-versus-kink rule states that damaged high-strength steel parts can be repaired if they are bent but must be replaced if they are kinked.
- A change in frame or unirail height is called kickup when the frame moves upward and sag when the frame moves downward.
- A change in frame or unirail length is called mash.
- The lateral movement of the rails is called sidesway.
- Twist damage is present when the frame rails or rocker panels are not level with each other.
- If the vehicle has diamond damage the center section of the vehicle no longer forms a rectangle.

Review Questions

Please do not write in this textbook. Place your answers on a separate sheet of paper.

1. List the factors that determine the grain pattern of steel.
2. ______ is the ability of metal to bend without permanent deformation.
3. Explain the difference between a buckle and a bend.
4. Work hardening ______ the strength of metal.
5. A(n) ______ crown panel has very little curvature.
6. What are the components of force?
7. ______ force is applied from one end.
8. Explain how a collapsed hinge buckle is formed.
9. ______ is the tendency of an object to remain at rest or in motion.
10. Explain how surface area of impact determines the amount of damage a vehicle sustains in a collision.
11. Explain the difference between direct and indirect damage.
12. The compression of grains is called ______.
13. A(n) ______ has a buckle that is greater than 90° in a short area.
14. All load bearing and structural parts of a damaged vehicle should be replaced if buckled. True or False?
15. A(n) ______ vehicle is designed to collapse during a collision, absorbing impact forces.

ASE-Type Questions

1. Technician A says that grains are formed by the crystalline pattern of the metal and alloy molecules. Technician B says that different types of metals have different grain patterns. Who is right?
(A) A only.
(B) B only.
(C) Both A and B.
(D) Neither A nor B.
2. Each of the following will affect elasticity of sheet metal EXCEPT:
(A) alloying elements.
(B) annealing process.
(C) humidity.
(D) shape.
3. Which of the following properties of metal indicates how readily the metal can be shaped by bending and stretching?
(A) Elasticity.
(B) Deformation.
(C) Plasticity.
(D) Inertia.
4. Technician A says that a low-crown panel will flex in and pop out. Technician B says that a reverse-crown panel flexes as much as a low-crown panel. Who is right?
(A) A only.
(B) B only.
(C) Both A and B.
(D) Neither A nor B.

5. Which of the following describes combination crown?
   (A) Curved in two directions.
   (B) Almost flat.
   (C) Curved into a convex shape.
   (D) Curved into a concave shape.
6. Technician A says inertia only acts on an object at rest. Technician B says that inertia only acts on an object in motion. Who is right?
   (A) A only.
   (B) B only.
   (C) Both A and B.
   (D) Neither A nor B.
7. Technician A says that a lateral impact at one end of a vehicle will cause the target vehicle to spin. Technician B says that vehicle height helps to determine how much damage results from a collision. Who is right?
   (A) A only.
   (B) B only.
   (C) Both A and B.
   (D) Neither A nor B.
8. Damage that occurs at the point of contact during a collision is called ______.
   (A) indirect damage
   (B) oblique damage
   (C) direct damage
   (D) target damage
9. Technician A says that a kinked high-strength unirail can be repaired. Technician B says that repairing a kinked high-strength unirail will cause the unirail to break. Who is right?
   (A) A only.
   (B) B only.
   (C) Both A and B.
   (D) Neither A nor B.
10. Which of the following types of damage is a change in the length of a frame rail?
    (A) Kickup.
    (B) Mash.
    (C) Twist.
    (D) Diamond.

Chapter 5

Welding and Cutting

Objectives

After studying this chapter, you will be able to:

- List the safety precautions required for welding.
- Describe the types of welds used in the collision repair shop.
- Explain the types of joints encountered during panel repair or replacement.
- Explain how to set up a MIG welding machine.
- Recognize MIG welding variables and explain how to control them.
- Explain how to make various types of welds using a MIG welding machine.
- Understand the differences between aluminum and steel welding.
- Recognize two types of resistance spot welding and know when each is used.
- Explain how to use a plasma cutter and cutting torch.

Technical Terms

auto-darkening helmet
bead
brazing
butt joint
butt joint with an insert
contact tube
continuous weld
duty cycle
electrode extension
fit up
flux-cored arc welding
flux-cored wire
gun orientation
lap joint
melt through
metal inert gas welding
MIG welding
nozzle
penetration
plug welds
push-pull wire feeder
resistance welding
rosebud tip
shade
skip welding
slag
spatter
spot weld
stick out
stitch weld
temperature crayon
TIG welding
travel direction
travel speed
tungsten inert gas welding
weld bonding
weld nugget
weld puddle
weld-through primer

Introduction

The ability to weld is an essential collision repair skill. A late-model vehicle is made up of many panels that are spot welded together. Replacing damaged panels on these vehicles requires welding. Welding is a skill that can be learned with instruction and practice. This chapter will present the various types of welds used in the collision repair shop. It will also describe how to use a plasma cutter and an oxyacetylene cutting torch.

Welding Safety

During welding operations, you must take steps to protect yourself, your co-workers, the vehicle you are repairing, and the shop. Welding produces sparks, heat, and bright light. Sparks are often thrown from the weld site. These sparks can burn skin or hair. The heat generated during the welding process can cause galvanized coatings to vaporize, producing a toxic gas. MIG welding produces bright light that can damage eyes and burn skin. You must recognize the dangers associated with welding and take steps to minimize them.

A welding helmet with an appropriate shade should be worn when welding. The helmet will protect your face, your neck, and the top of your head. The ***shade*** is a glass lens that filters out harmful infrared and ultraviolet light. When MIG welding, you should wear a helmet with a #10 shade. A major problem when MIG welding is that the #10 shade is so dark that nothing can be seen through the shade until the arc is struck, producing light. The technician must start the weld without being able to see the work surface. An ***auto-darkening helmet*** eliminates this problem because the shade is clear until the arc is struck. The technician can see the workpiece before beginning to weld. Once the arc is struck, the shade becomes dark. See **Figure 5-1**.

WORKING SMART

Most technicians know not to look at the arc produced by the MIG welding machine. However, in the close confines of some body shops, this may be difficult. A welding shield can be set up to screen the weld area from the co-workers.

Welding gloves should be worn to shield your hands and wrists from sparks and hot metal. A welding cape or jacket should be worn to protect your clothes and body from burns. Wear leather boots to protect your feet. Sparks produced during welding will bounce off flat surfaces but will catch and burn in cuffs and low-cut shoes. A welding respirator filters out harmful vapors generated when welding galvanized steel. In addition to wearing a respirator, you should weld only in a well-ventilated area. A technician wearing appropriate welding safety gear for welding nongalvanized steel is shown in **Figure 5-2**.

Welding can cause a vehicle to catch fire. Glass, paint, and upholstery can be pitted or burned by sparks. In MIG and resistance spot welding, electric current passes through the metal of the vehicle. This current can damage electronic components. Before welding,

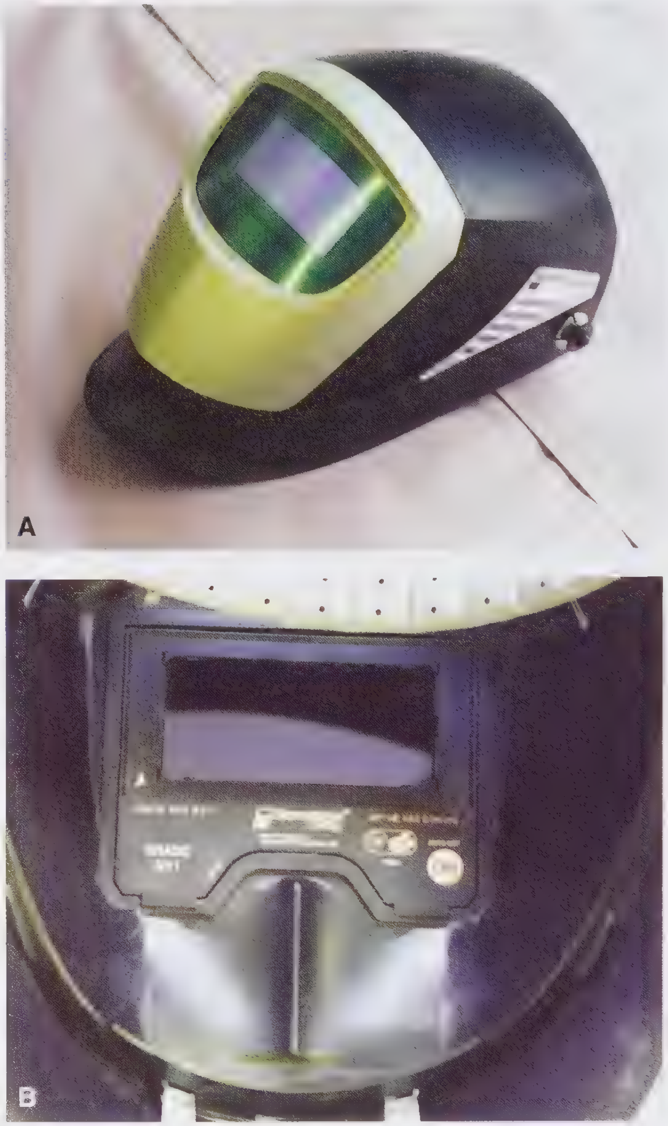


Figure 5-1. *The shade of an auto-darkening welding helmet is clear until the arc is struck, allowing the technician to see the work before welding begins. A—Outside view. B—Inside view.*

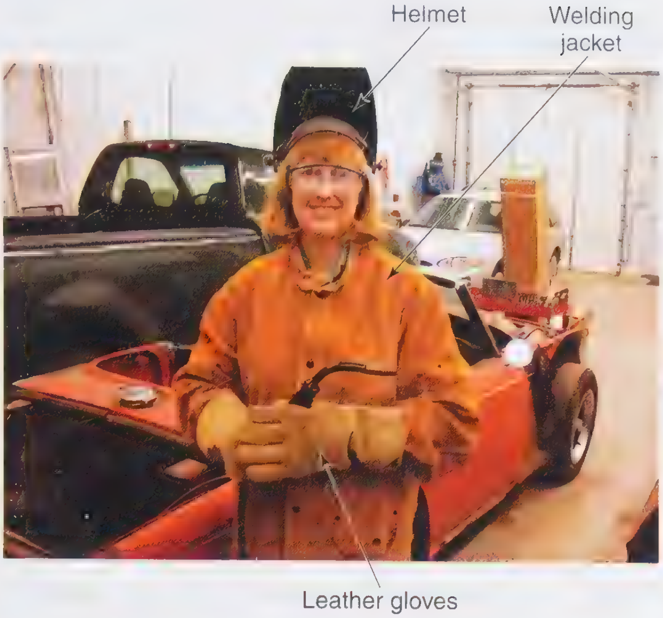


Figure 5-2. *This technician is wearing MIG welding safety equipment for welding nongalvanized steel.*

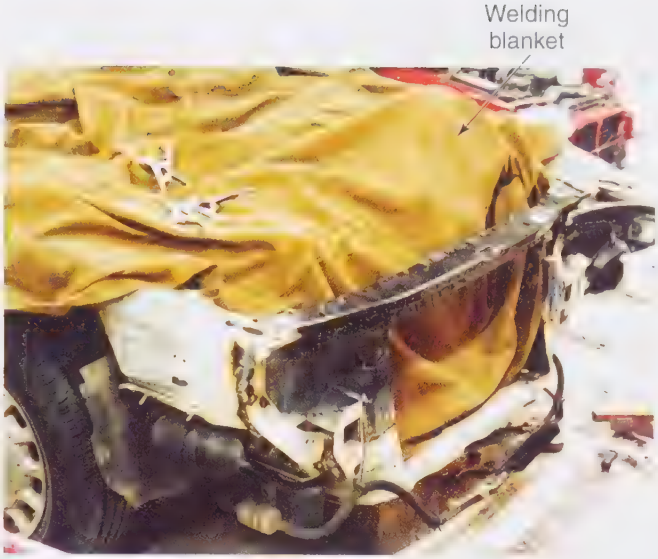


Figure 5-3. *A leather blanket is used to cover the engine compartment when welding a radiator support.*

disconnect the negative battery cable and secure the cable so it cannot touch the negative terminal. This opens the electrical circuit in the vehicle, minimizing the travel of electric current.

If welding will be done within 12" (30 cm) of an electronic component, remove the component to prevent damage. For example, the turn signal flasher module in one particular vehicle is bolted to the inside of the A pillar at the kick panel. Before welding in a new A pillar or rocker panel, this part must be removed. On some vehicles, the air bag module is bolted under the right front seat. This module must be removed before welding nearby panels. Electronic parts can also be damaged by static electricity. Wear a ground strap when removing these parts and store them in an anti-static bag.

Cover all surfaces near the weld area. See **Figure 5-3**. Leather welding blankets are thick enough to provide adequate protection, even when laid flat. A plastic welding blanket is not thick enough to protect the vehicle when laid flat. It is designed to hang and deflect sparks. A spark that does not bounce off may burn through a plastic blanket, damaging the vehicle.

Remove all undercoating from the back side of a panel before welding the panel. The heat generated during the welding process may ignite the undercoating. It is a good practice to stop welding about one hour before the end of the workday. A spark can sometimes smolder for several minutes before causing flames. If a technician finishes welding at quitting time and everyone leaves the shop, the vehicle may catch fire when nobody is around to put it out.

Welding sparks can be thrown as far as ten feet from the weld area. Remove any combustible materials from the vicinity of the weld. Combustible materials include paper, masking materials, thinner, shop rags, cardboard, and paint.

Never set up an electric welding machine on a wet surface or run its power cord along a wet floor. Keep the use of extension cords to a minimum. A long cord transmits less voltage to the welding machine and may cause more heat to build up in the cord. Never use a light-duty extension cord.

Care must be taken when working with welding-gas cylinders, such as oxygen or acetylene cylinders. Chain the cylinders to the cart or the wall to prevent tipping. If a cylinder were to fall, breaking the cylinder valve, the tank could be propelled violently around the shop until all the gas escapes. Before moving cylinders, be sure to install their safety caps. These caps protect the cylinder valves from damage. Cylinders should be moved using a proper cart or by tilting them and rolling them along their bottom edge.

WARNING

Never use acetylene at a working pressure (pressure of gas that flows to the torch) above 15 pounds per square inch (psi). Above this pressure, acetylene is unstable and may explode.

Welding Fundamentals

Welding is the process of joining metals together using heat. There are several considerations that must be taken into account when welding during. The following sections discuss the various weld types, weld positions, and joint types commonly encountered in the collision repair shop. It also details importance of proper fit up and explains how to prepare metal for welding.

Most auto body welding is done in a way to minimize heat buildup. Excessive heat warps panels, especially low-crown panels, and weakens high-strength steel. Keep heat buildup to a minimum by making short beads

Weld Types

There are three basic types of welds used in the collision repair shop, **Figure 5-4**. The ***stitch weld*** is a short bead that is not more than 3/4" (20 mm) long. Stitch welds can be made by striking the arc and moving the gun. These short welds may also be called *tack welds*. A series of stitch welds can be strung together to form a ***continuous weld***. See Figure 5-4A.

A ***spot weld*** is a small fused area, commonly referred to as the ***weld nugget***. See Figure 5-4B. When making a spot weld, an arc is struck but the gun is not moved. ***Plug welds*** are used to duplicate factory spot welds on structural parts. See Figure 5-4C.

Welding Position

Welds are made in one of four positions: flat, horizontal, vertical, or overhead. See **Figure 5-5**. In the flat position, both the weld and the panel are horizontal, Figure 5-5A. Welding in this position is relatively easy. In the horizontal position, Figure 5-5B, the panel is vertical and the weld is horizontal. In this position, the weld can be made from left to right or from right to left.

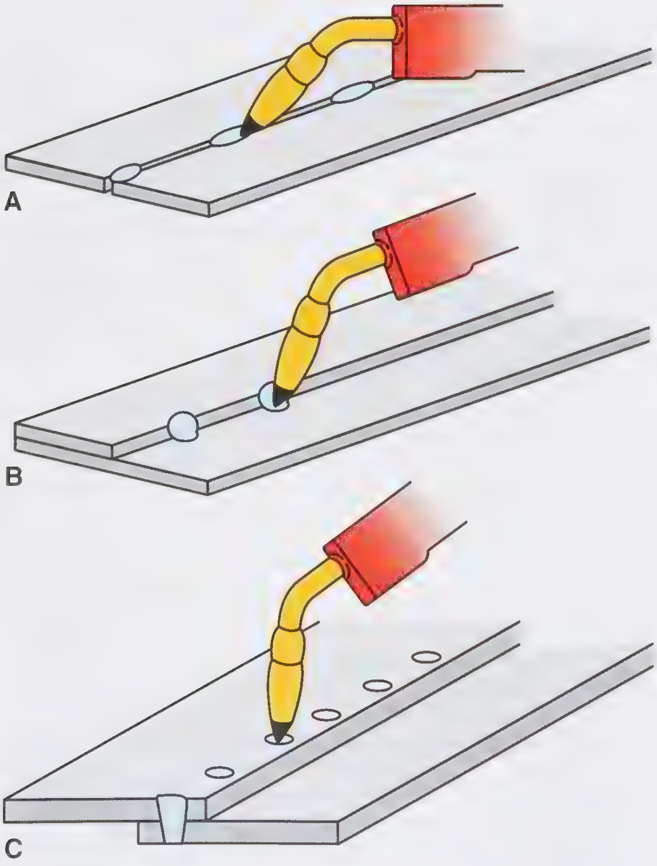


Figure 5-4. *A—The stitch weld procedure can be used to make a continuous weld. B—A spot weld produces the minimum amount of heat in the metal surrounding the weld. C—Plug welds are made by welding around the perimeter of a hole.*

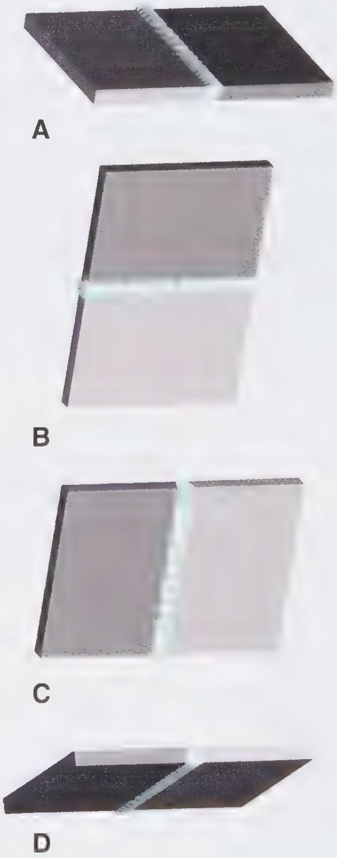


Figure 5-5. *Welding positions. A—Flat. B—Horizontal. C—Vertical. D—Overhead.*

In the vertical position, the panel is again vertical, but the weld is made vertically (up or down). See Figure 5-5C. Horizontal and vertical welding positions are very common in collision repair welding. In the overhead welding position, the panel and weld are horizontal, but the weld is made from the underside of the panel. Overhead is the most difficult welding position to master. The overhead welding position is shown in Figure 5-5D.

Joint Types

Joints are how the panels are positioned before welding. See **Figure 5-6**. The types of joints commonly used in collision repair include the following:

- A ***butt joint***, Figure 5-6A, is made with two panels that are aligned edge to edge. The weld is made between the two panels.
- In a ***butt joint with an insert***, Figure 5-6B, the panels are aligned edge to edge and another panel, the insert, is positioned below the joint to connect the panels. The panels are plug welded to the insert and then the gap between the panels is stitch welded.
- A ***lap joint*** is shown in Figure 5-6C. In a lap joint, one panel is placed on top of another. The edge of the top panel is welded to the bottom panel. The upper panel can also be plug welded to the lower panel. If a flange is made in one of the panels, the panels will be flush after welding. Figure 5-6D shows a lap joint in which one panel is flanged.

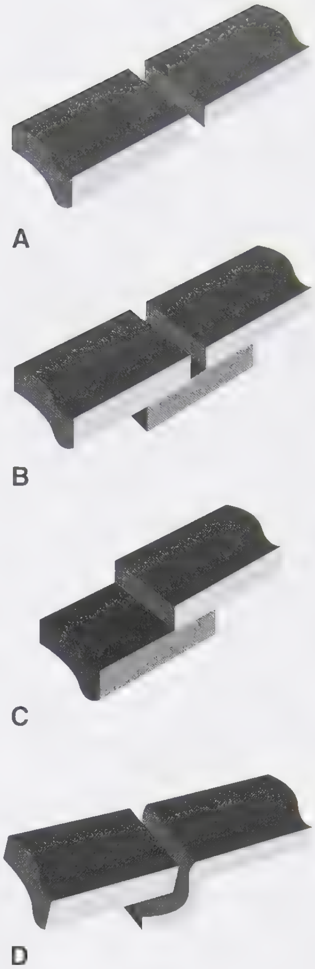


Figure 5-6. *Typical joint types. A—The butt joint has a slight gap between the edges of the aligned panels. B—In a butt joint with an insert, two panels are placed edge to edge with a slight gap between them. A smaller panel, or insert, connects the two main panels. C—In a lap joint, one panel is placed on top of the other. D—This is a flange-type joint. A step is made in the top panel.*

Fit Up

Fit up is a quality that is often overlooked. Panels to be lap welded must be tightly fitted, with no gaps. A gap between lapped panels will cause melt through because the heat of the weld is concentrated on one panel instead of both. ***Melt through*** occurs when the heat from the weld melts away the base metal. Fit up can be maintained with clamps or sheet metal screws.

Preparation for Welding

Metal must be prepared properly before welding. The best welds result from bare-metal-to-bare-metal contact between the two panels. Remove paint from the panels to be welded by sanding with 80-grit sandpaper. Do not remove metal by grinding. Remove any other type of contamination. Apply weld-through primer to the bare metal before fit up. The ***weld-through primer*** protects the bare metal inside the joint after the panels have been welded.

MIG Welding

As previously mentioned, ***MIG welding***, or ***metal inert gas welding***, is the most common type of welding performed in the collision repair facility. During the MIG welding process, an electric arc is created between an electrode wire and the metal. The electrode wire and the metal melt from the heat of the arc. This creates an area of molten wire and metal called the ***weld puddle***. Electrode wire is constantly fed into the weld puddle. A shielding gas protects the weld puddle from contamination. MIG welding machines are sometimes called wire-feed welding machines.

NOTE

The term *metal inert gas welding* is somewhat misleading. The shielding gas used in this process may or may not be inert. A combination of argon (inert) and carbon dioxide (not inert) is commonly used. Therefore, a more fitting name for the process is *gas metal arc welding*, or *GMAW*. However, the term *MIG welding* is customarily used in the collision repair industry and, therefore, will be used in this textbook.

A MIG welding machine is shown in **Figure 5-7**. The major parts of a typical MIG welding machine include:

- Power cord—The power cord is plugged into an appropriate outlet. Light-duty MIG welding machines (up to 125 amps) operate on 115 V AC. More powerful welding machines (up to 270 amps) operate on 230 V AC. A light-duty welding machine is adequate for sheet metal, but full-frame welding requires a welding machine rated at 200 amps or above.
- Work clamp—The work clamp must contact the workpiece in order to complete the electrical circuit. An arc cannot be generated if the work clamp is not attached to bare metal. Attach the work clamp as close as possible to the weld area.
- Wire feeder—The wire feeder feeds the welding wire to the welding gun. It consists of the spool, the drive rollers, and the tension spring. The wire spool contains the welding wire. The rotating drive rollers pull the welding wire from the spool. The welding wire fits into a groove in the drive rollers. The groove in the drive roller must be the proper size for the diameter of the welding wire being used. Some rollers contain two grooves for different wire diameters. If necessary, the drive rollers can be changed to accommodate different wire diameters. The tension spring applies pressure to the welding wire at the drive rollers. As the drive rollers turn, the welding wire is pulled off the spool and pushed into the welding cable. Welding wire is identified by a code printed on the wire's container or package. The code is based on a standard rating system devised by the American Welding Society. The most commonly used welding wire is AWS ER70S-6. See **Figure 5-8**. AWS ER70S-7 welding wire is also acceptable for use in auto body repair. Most welding wires contain deoxidizers, which react with oxygen, nitrogen, or hydrogen to prevent these gases from affecting the strength of the weld.
- Shielding gas bottle—The shielding gas bottle is a cylinder used to store shielding gases at high pressure. MIG welding machines used for collision repair of steel use a mixture of 75% argon and 25% carbon dioxide.

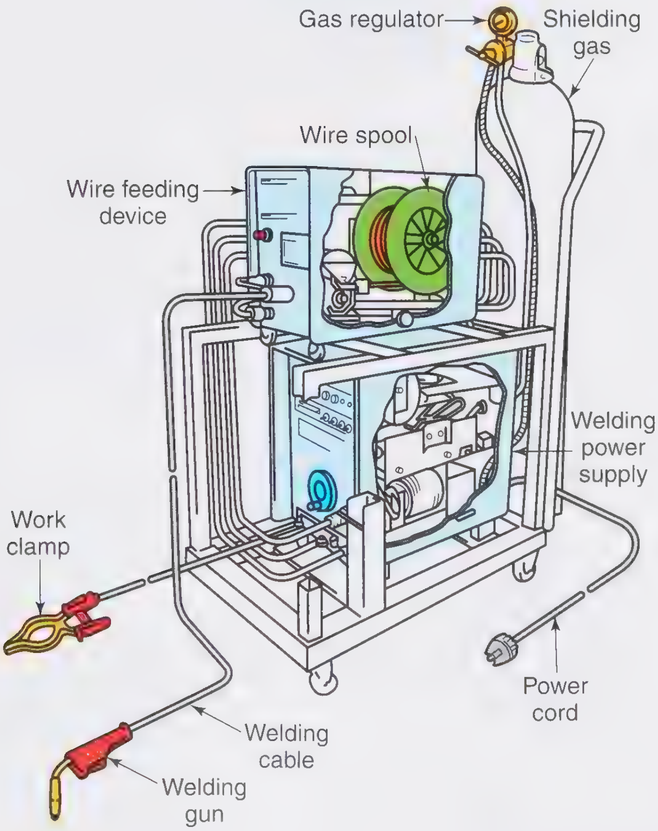


Figure 5-7. *The parts of a MIG welding machine are illustrated above. Most MIG welding machines are similar in construction. (Toyota)*

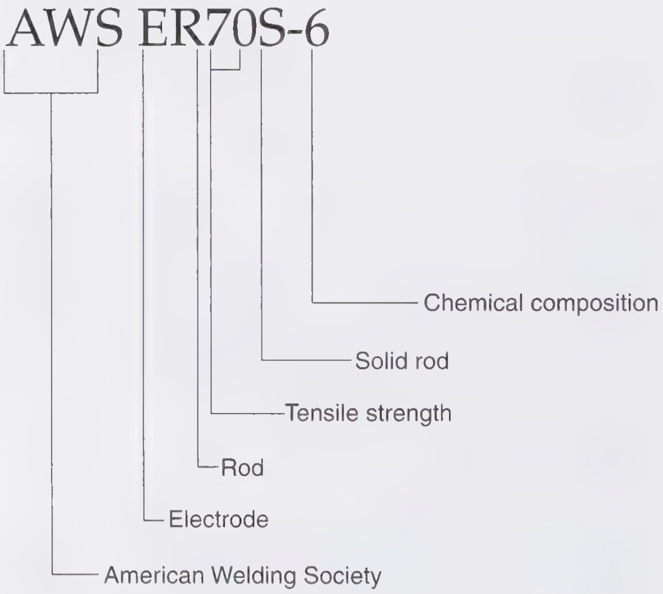


Figure 5-8. *AWS ER70S-6 wire is commonly used when MIG welding steel during body repair. The E stands for electrode wire, the R stands for rod, the 70 means 70,000 psi tensile strength, the S stands for solid wire, and the 6 indicates the chemical composition of the wire and the ability to keep oxygen out of the weld.*

- Shielding gas regulator—The shielding gas regulator reduces the pressure in the shielding gas bottle to the appropriate working pressure. It determines how much shielding gas is dispensed whenever the wire moves. The operating instructions included with the welder should specify the volume of shielding gas required. Some regulator gauges measure volume in cubic feet per minute (cfm); other gauges measure it in pounds per square inch (psi). The gauge should be set at 12–30 cfm or 3–4 psi. A breeze in the weld area will displace the shielding gas. Therefore, you should use a slightly higher volume of shielding gas if there is significant air movement in the weld area.
- Heat control (voltage)—This knob sets the voltage. See **Figure 5-9**. There is a direct relationship between voltage, arc length, and heat. The voltage determines the size of the arc. The size of the arc determines the amount of heat produced. As the voltage increases, the arc increases in both size and temperature.
- Wire speed (amps) control—The wire speed is balanced to the heat (voltage) setting. The wire speed setting is determined by the thickness of the metal to be welded and the diameter of the welding electrode.
- Power switch—Used to turn the machine on and off.
- Welding gun—The welding gun makes electrical contact with the welding wire and directs the shielding gas toward the weld. When the gun's trigger is pulled, the welding wire moves through the gun, and electrical current and shielding gas begin to flow. The gun's ***nozzle*** directs the gas flow around the welding wire. A ***contact tube*** screws into the end of the gun and establishes a good electrical connection between the gun and the welding wire. See **Figure 5-10**. The hole in the contact tube is matched to the welding wire diameter. The contact tube and nozzle must be kept clean. When the trigger is released, the wire and the current stop, but the shielding gas may continue to flow for a short time to continue shielding the weld and to cool the gun.

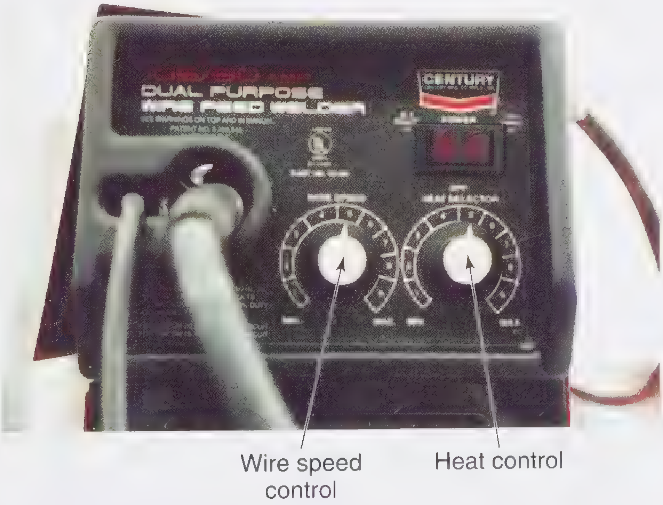


Figure 5-9. *MIG welding machine settings include heat (voltage) and wire speed (amps).*

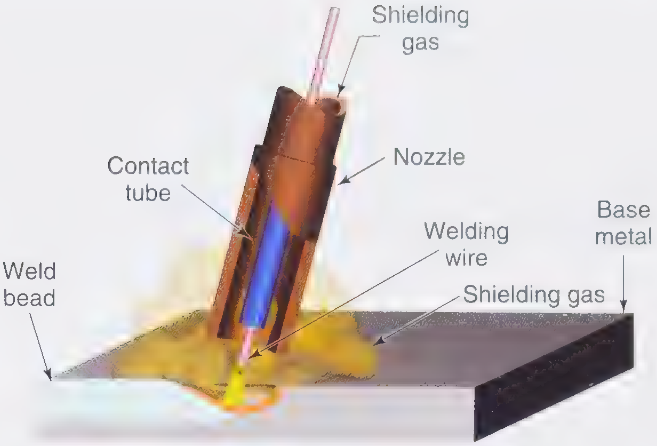


Figure 5-10. *This illustration shows the orientation of the gun's nozzle and contact tube, as well as the welding wire. Note the shielding gas, which protects the weld from contamination.*

- Welding cable—The welding cable connects the welding gun to the welding machine. The cable is the pathway that carries the welding wire and shielding gas from the welding machine to the welding gun. The welding wire moves inside a liner. A steel liner is used for steel welding wire. Aluminum welding wire requires a Teflon™ liner.

A MIG welding machine can be set up to use ***flux-cored wire***. Flux-cored wire does not require shielding gas. The wire is a tube with flux in the center. The heat of the welding process vaporizes the flux, and the flux vapor protects the weld from contamination.

MIG welding machines are rated based on their duty cycle. The ***duty cycle*** is the length of time, expressed as a percentage, that a welding machine can operate in a 10-minute period at a particular heat setting. Duty cycle can range from 20%–100%. At 20% duty cycle, the welding machine can weld for two out of ten minutes without damage. The welding machine can overheat if the duty cycle is exceeded. For each two minutes of welding, the welding machine must be allowed to "rest" for eight minutes. During the rest period, the welding machine cools down. At a low heat setting, the welding machine may have a 100% duty cycle, which means it does not require any rest. As the heat setting increases, the duty cycle decreases. After welding, allow the welding machine to run for about ten minutes to cool down before shutting it off. Keep the inside of the welding machine clean. Dust may cause the welding machine to run hot.

Welding wire should never be stored in a damp area. If the wire rusts, it can ruin the welding machine. A wire cleaner, **Figure 5-11**, can be installed to brush the wire off as it is fed into the rollers. Oil may be added to the felt of the cleaner to lubricate the wire. An antispatter spray can be applied to the nozzle to keep spatter from sticking. ***Spatter*** is the hardened remains of molten metal that is thrown about during the welding process.

Weld Terminology

MIG welding creates a ***bead***. A MIG weld bead is made from the melted welding wire. Some aspects of a bead are shown in **Figure 5-12**. Bead height is determined by how much wire is deposited. ***Penetration*** is the depth of melting. The melting should be deep enough to cause rippling on the back side of the weld. Too much penetration will cause melt through. Insufficient penetration (no ripple on the back side of the metal) will result in a weak weld.

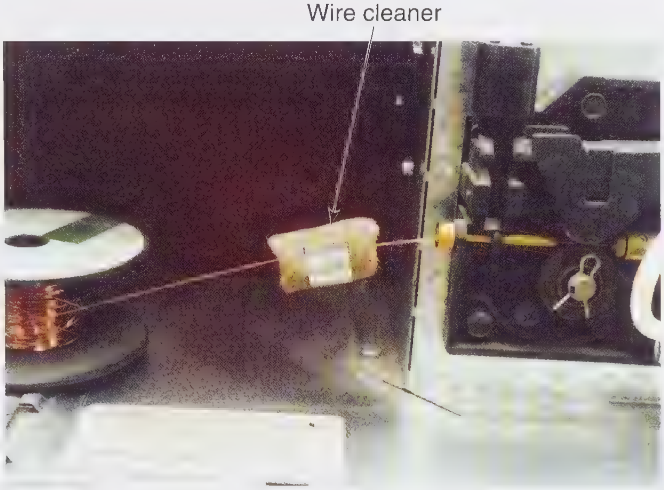


Figure 5-11. *The wire cleaner is installed between the wire spool and the drive rollers.*

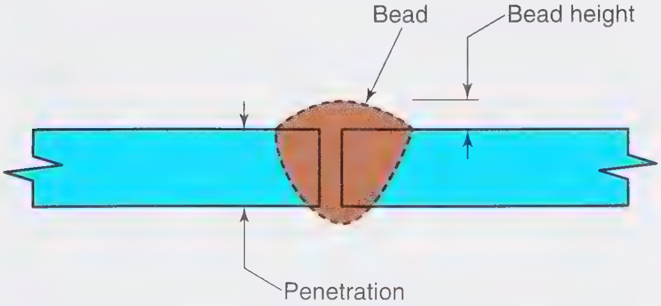


Figure 5-12. *Weld bead terminology. Excessive bead height will increase the time required to grind down the weld.*

MIG Welding Variables

There are several variables that must be taken into consideration when MIG welding. Some of these variables involve the setup and adjustment of the welding machine. Others relate to the way the technician performs the welding procedure.

The variables that involve the welding machine include wire diameter, the wire speed/amps setting, and the voltage/heat setting.

The wire diameter selected depends on the thickness of the metal to be welded. As shown in **Figure 5-13**, welding thicker metal requires larger diameter wire. Larger wire is capable of carrying more amperage than smaller wire.

The wire speed/amps setting also depends on the thickness of the metal to be welded. As a general rule, 1 amp is required for each 0.001" (0.025 mm) of metal thickness. The welding machine should have a chart that lists the settings for wire speed/amps and voltage/heat for various metal thicknesses. A wire speed/amp setting that is too high will cause melt through, burning a hole in the metal instead of just melting it. A wire speed/amp setting that is too low will not melt the metal enough, which will lead to insufficient penetration, or incomplete fusion.

The voltage/heat setting is balanced with wire speed/amps setting to achieve a stable arc. If the wire speed/amp setting is increased, the voltage/heat setting should be increased. If the wire speed/amp setting is decreased, voltage/heat setting should be decreased. Galvanized metal requires slightly higher voltage/heat and wire speed/amp settings than nongalvanized metal. Set each dial one setting higher than the recommended settings for mild steel. For example, if welding 20-gauge steel requires a voltage setting of 5 and a wire speed setting of 6, galvanized 20-gauge steel would require a voltage setting of 6 and a wire speed setting of 7.

Variables that the technician can influence include gun orientation, travel speed, travel direction, and stick out. ***Gun orientation*** is the angle that the welding gun is held at in relation to the workpiece. See **Figure 5-14**. The type of weld being made determines gun orientation. Plug welds are made with the gun held at a 90° angle to the workpiece. See Figure 5-14A. Lap welds are made with the gun at an angle between 60° and 75°. The steeper angles are used for thicker metals. See Figure 5-14B. The gun should be held at a 70° angle when making butt welds. See Figure 5-14C. For a butt joint with an insert, the gun should be held at a 90° angle. A low MIG gun angle (less than 60°) will cause arc instability, increased spatter, less penetration, and less shielding gas coverage.

When making a plug or stitch weld, the arc is started and the gun is moved. The rate at which the gun moves is called ***travel speed***. Travel speed depends on the wire speed/amps setting and the voltage/heat setting. Adjust the travel speed while welding to achieve sufficient penetration with no melt through.

Panel Thickness mm (in.) Wire Diameter mm (in.)	0.6 (0.024)	0.8 (0.031)	1.0 (0.039)	1.2 (0.047)	1.6 (0.063)	2.3 (0.091)	3.2 (0.126)
0.6 (0.024)	20~30 A	30~40 A	40~50 A	50~60 A			
0.8 (0.031)			40~50 A	50~60 A	60~90 A	100~120 A	
0.9 (0.035)					60~90 A	100~120 A	120~150 A

Figure 5-13. *This chart shows the relationship between wire diameter, metal thickness, and amperage. (Toyota)*

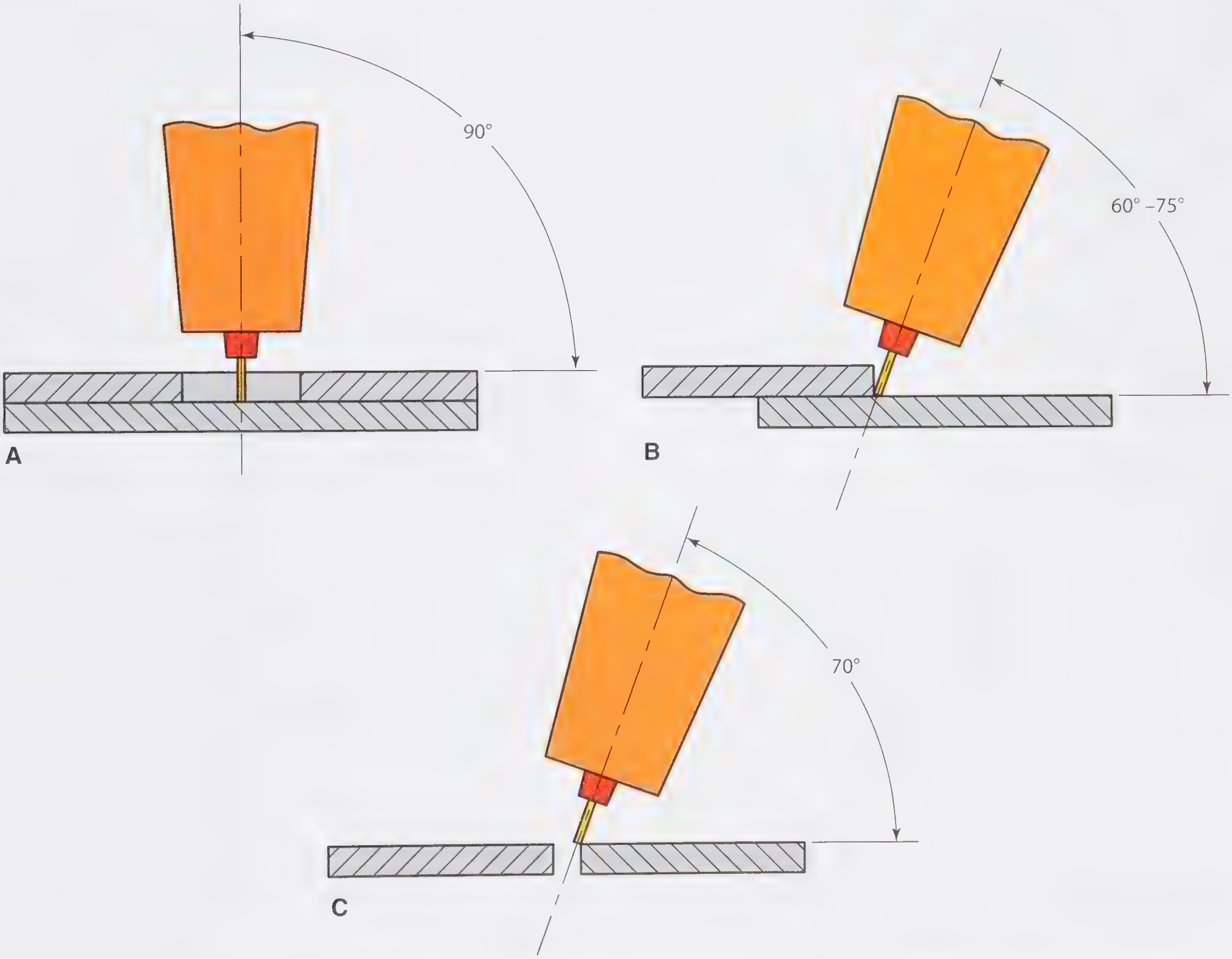


Figure 5-14. *A—The gun should be held perpendicular to the panel when making a plug weld. Position the MIG wire so it touches the bottom panel and the edge of the hole. B—Hold the gun at a 60°–75° angle when making a lap weld. C—Use a 70° angle when making a butt weld. This will allow the weld to bridge the gap from one panel to another.*

Travel direction is the direction in which the gun is moved when making the weld. The gun can be moved left to right, right to left, bottom to top, or top to bottom. The orientation of the gun in relation to travel direction has an effect on weld penetration. Pulling involves holding the gun so that the tip of the welding wire points opposite the gun's travel direction. This method pulls, or drags, the weld puddle. Pulling produces a narrow weld bead with deep penetration and is best suited for welding 1/8" or thicker steel. Pulling is often referred to as the backhand method of welding.

Pushing is done with the gun held so that the tip of the wire points toward the gun's travel direction. This method pushes the weld puddle. It produces a wide weld bead with shallow penetration. Pushing is commonly called the forehand method of welding and is best suited for welding sheet metal.

Electrode extension, or ***stick out***, is the length of the wire protruding from the welding gun's contact tube. It determines the distance between the contact tube and the panel. See **Figure 5-15**. Electrode extension should be 1/4"–3/8" (6–9 mm) for 0.023–0.030 wire and 3/8"–1/2" (9–12 mm) for 0.035 wire. It can be varied within a range to fine-tune the weld. If electrode extension is too short, the wire will melt inside the contact tube, stopping wire movement through the cable and causing a bird's nest inside the welding machine. If it is too long, a weak weld will result.

It is important that the technician be able to see the weld puddle in any type of MIG welding. By observing the weld puddle, the technician can make needed changes in travel speed and stick out.

Vertical welds are most often made in the vertical down position. Vertical down welds start at the top of the panel and move toward the floor. The welding machine must be adjusted slightly higher on vertical down welds. When making a vertical down weld, position the MIG gun so it points down slightly. This will place the wire at the leading edge of the weld puddle. Point the MIG gun slightly upward when making vertical up welds. Vertical up welds are made at lower wire speed/amps and volts/heat settings than vertical down welds. The travel speed is also slower, increasing penetration. Vertical up welds should be avoided on sheet metal panels because the slow travel speed and increased penetration tend to cause melt through.

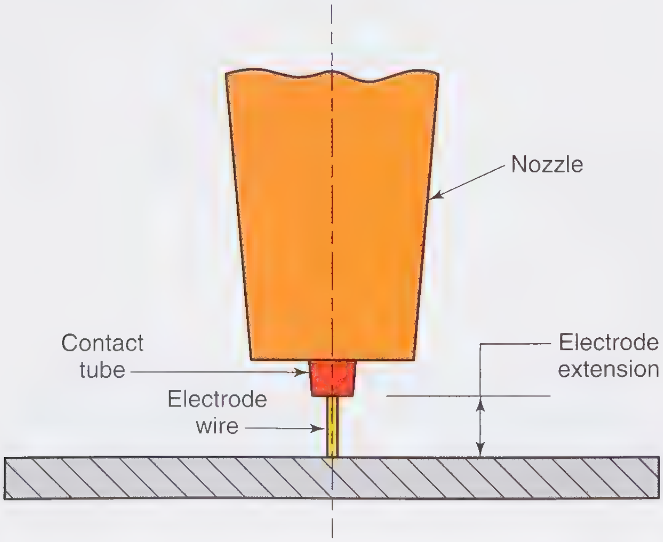


Figure 5-15. *The length of wire protruding from the contact tube determines the distance between the tip and the panel.*

Overhead welds are difficult to make because molten metal may drip out of the weld and clog the wire feed or gas flow. Do not position the gun at a 90° angle. Instead, angle the gun in the pushing direction.

In addition to these variables, the weld type and the joint type must be taken into account. These topics were discussed earlier in this chapter.

MIG Welding Machine Setup

Successful MIG welding requires a properly adjusted welding machine. In the previous section, numerous welding variables were discussed. All these variables must be taken into account when setting up the welding machine. The steps in setting up the welding machine are as follows:

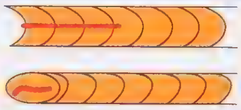
1. Check the thickness of the metal to be welded. There must be bare metal in the weld area and at the work clamp attachment site.
2. Check the label inside the welding machine for initial set-up values for voltage/heat and wire speed/amps.
3. Dial in the set-up values on the welding machine and adjust the gas flow to the specified value.
4. Place a metal workpiece flat on the table or on the floor. Attach the work clamp to the workpiece.
5. Put on all required safety gear.
6. Hold the gun at a 90° angle to the workpiece with the right amount of electrode extension. Do not change the orientation of the gun or move the gun from the start position. If the gun moves, the weld will be made in the wrong place. It can be difficult, but it is essential not to move the gun before striking the arc.
7. Lower the welding helmet.
8. Pull the trigger on the gun and move the gun at a rate of approximately 1" (25 mm) every 2 seconds.
9. There should be a steady buzz and an even light.
10. The process of adjusting the welder to get the settings just right is called tuning in. To tune in the welder, leave the amps/wire speed at the specified value and turn the voltage/heat knob above and below the initial setting to obtain the steady buzz of a good weld. If changing voltage/heat setting does not obtain a good weld for the specified amp/wire speed setting, change the amps/wire speed. Then, adjust the voltage/heat to obtain a steady buzz with the new amp/wire speed setting. Always set the voltage/heat setting to match the amps/wire speed setting.

Making Welds Using a MIG Welding Machine

Making good MIG welds requires that the technician wear the proper safety gear, that the MIG welder adjustments be set properly, and that the technician use the right technique. The following section explains how to make the common welds used in the collision repair shop.

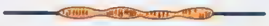
Figure 5-16 shows weld defects and lists possible causes. Become familiar with the causes of these defects so you avoid these problems.

MIG Welding Problems

Defect	Appearance
Cracks in the weld	

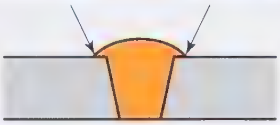
Cause

- Stains (oil, paint, rust) on base metal
- Heat (voltage) and wire speed (amperage) too high

Defect	Appearance
Distortion (wavy or inconsistent weld bead)	

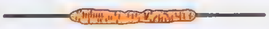
Cause

- Contact tip too large or worn, causing electrode to shift as it comes out
- Stick out too long, allowing electrode to melt and wander as it comes out
- Unsteady hand
- Wire speed (amperage) not consistent
- Heat setting too high, causing electrode to melt off in large drops, with thin areas in between

Defect	Appearance
Overlap (weld metal rolls over too much on each side of weld	

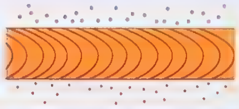
Cause

- Wire speed (amperage) too high
- Heat (voltage) too low
- Travel speed too slow

Defect	Appearance
Porosity (cracks in the weld)	

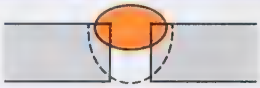
Cause

- Not enough shielding gas caused by:
  - Gas not turned off
  - Flow set too low or high
  - Breeze in the weld area
  - Leaks in gas hose
  - Pinched gas hose
  - Loose hose fitting
  - Cuts in hose
  - Damaged O-ring seal on fitting
  - Frozen CO_2 regulator
  - Spatter on gun nozzle
  - Too much electrode stick out, spreading the shielding gas
  - Wrong shielding gas
  - Wrong electrode
  - Dirt on electrode
  - Contaminants on base metal

Defect	Appearance
Spatter (drops of weld metal around weld area)	

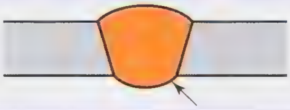
Cause

- Worn contact tip
- Wire spool too tight
- Wrong size electrode
- Heat (voltage) too high, making arc length too long
- Drive rolls wrong size or worn
- Gun angled up or down too much
- Dirt or rust on base metal
- Shielding gas flow not high enough

Defect	Appearance
Too little penetration	

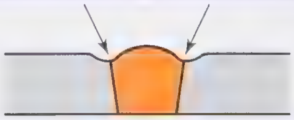
Cause

- Heat (voltage) and wire speed (amperage) settings not high enough
- Incorrect gun angle (aim more at thicker base metal)
- Travel speed too fast
- Stick out too long, causing electrode to melt before penetrating deep enough. Stick out should be about 1/4" (6 mm)
- Gun not aimed at joint

Defect	Appearance
Too much penetration (burn through)	

Cause

- Heat (voltage) and wire speed (amperage) settings too high for thickness of metal
- Travel speed too slow, allowing too much time for heat to burn through
- Gap between butt joint too large, allowing too much heat to penetrate
- Stick out too short, heating electrode too much as it contacts base metal

Defect	Appearance
Undercut (small groove cut into base metal on one or both sides of weld, reducing weld strength)	

Cause

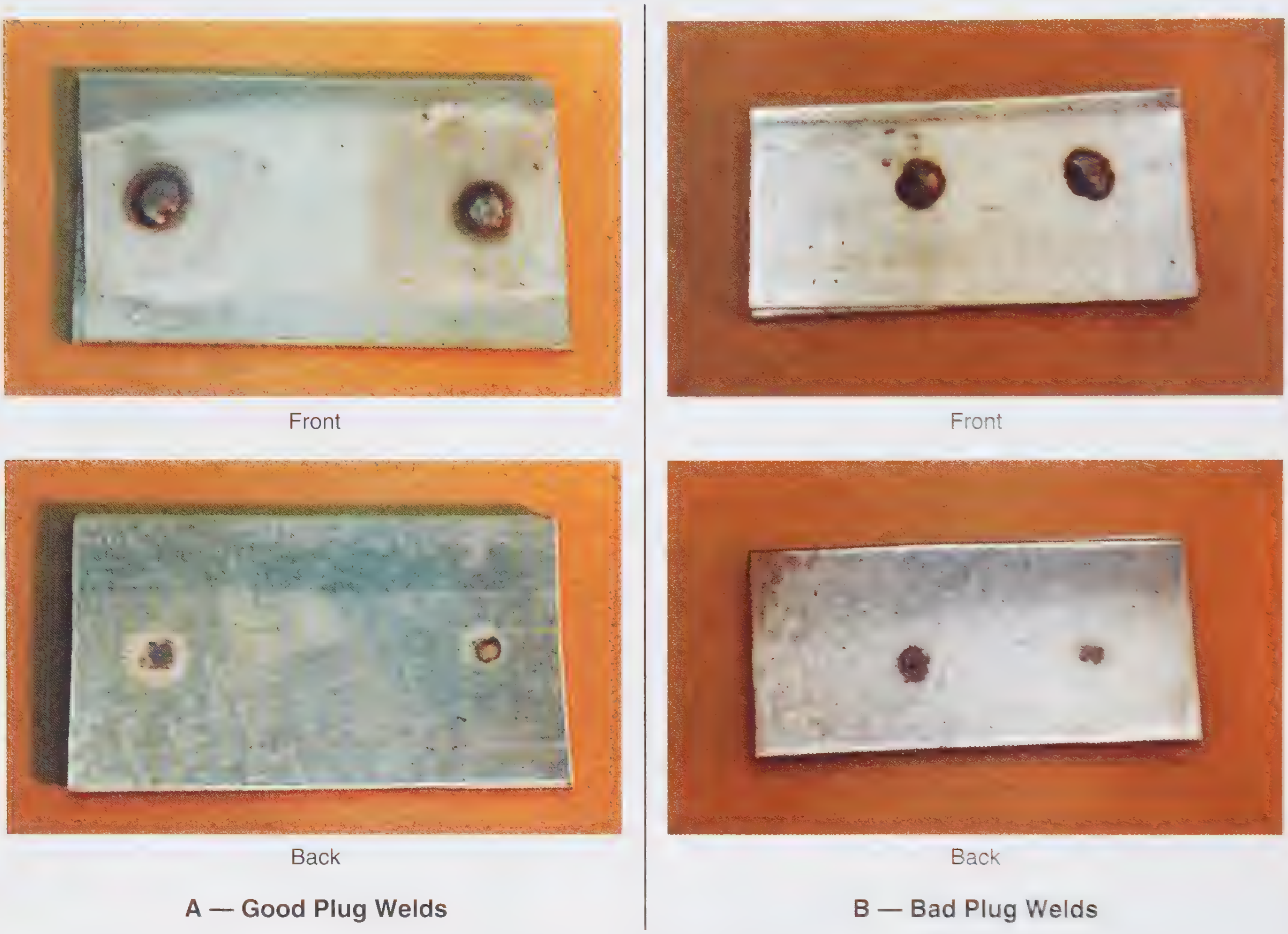
- Wire speed (amperage) too high
- Heat (voltage) too high
- Wrong gun angle (not aimed at joint)

Figure 5-16. *This diagram summarizes MIG welding problems.*

Plug Weld

A plug weld is most commonly used with a lap joint. The size of the plug hole is determined by the thickness of the metal. A 3/16" (5 mm) hole is used for 24 gauge or thinner metal, a 5/16" (8 mm) hole is used for 22–16 gauge metal, and a 3/8" (9 mm) hole is used for 14 gauge or thicker metal. The most common hole size for collision repair work is 5/16" (8 mm). After drilling the proper size hole, position the gun at 90° to the workpiece and align the welding wire so it touches the bottom piece of metal and the edge of the hole. Refer back to Figure 5-14. Weld all the way around the perimeter of the hole without stopping or hesitating. **Figure 5-17** shows good and bad plug welds.

Plug welds can also be used to hold three pieces of metal together. See **Figure 5-18**. The bottom piece has no hole, the middle piece has a hole of the specified diameter


Front

Back

A — Good Plug Welds

Front

Back

B — Bad Plug Welds

Figure 5-17. *A—Good plug welds. Look for an even, circular weld on the top side. Ripple and a heated zone should be visible on the back. B—These are bad plug welds. They do not fill the hole and there is little penetration on the back side of the metal. These welds are weak.*

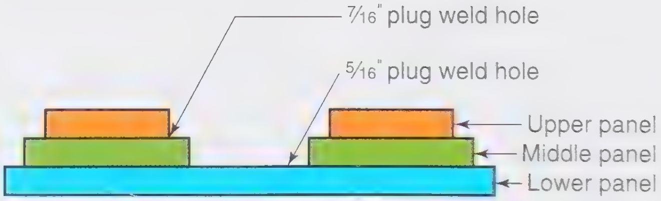


Figure 5-18. *Three layers of metal can be plug welded. The middle layer plug hole is 5/16", while the upper layer plug hole is 7/16".*

for that thickness of metal, and the top piece has a hole that is 1/8" (3 mm) larger than the middle hole. Weld around the perimeter of the middle hole first. This will secure the middle piece to the bottom piece. After allowing the first weld to cool, weld around the perimeter of the upper hole.

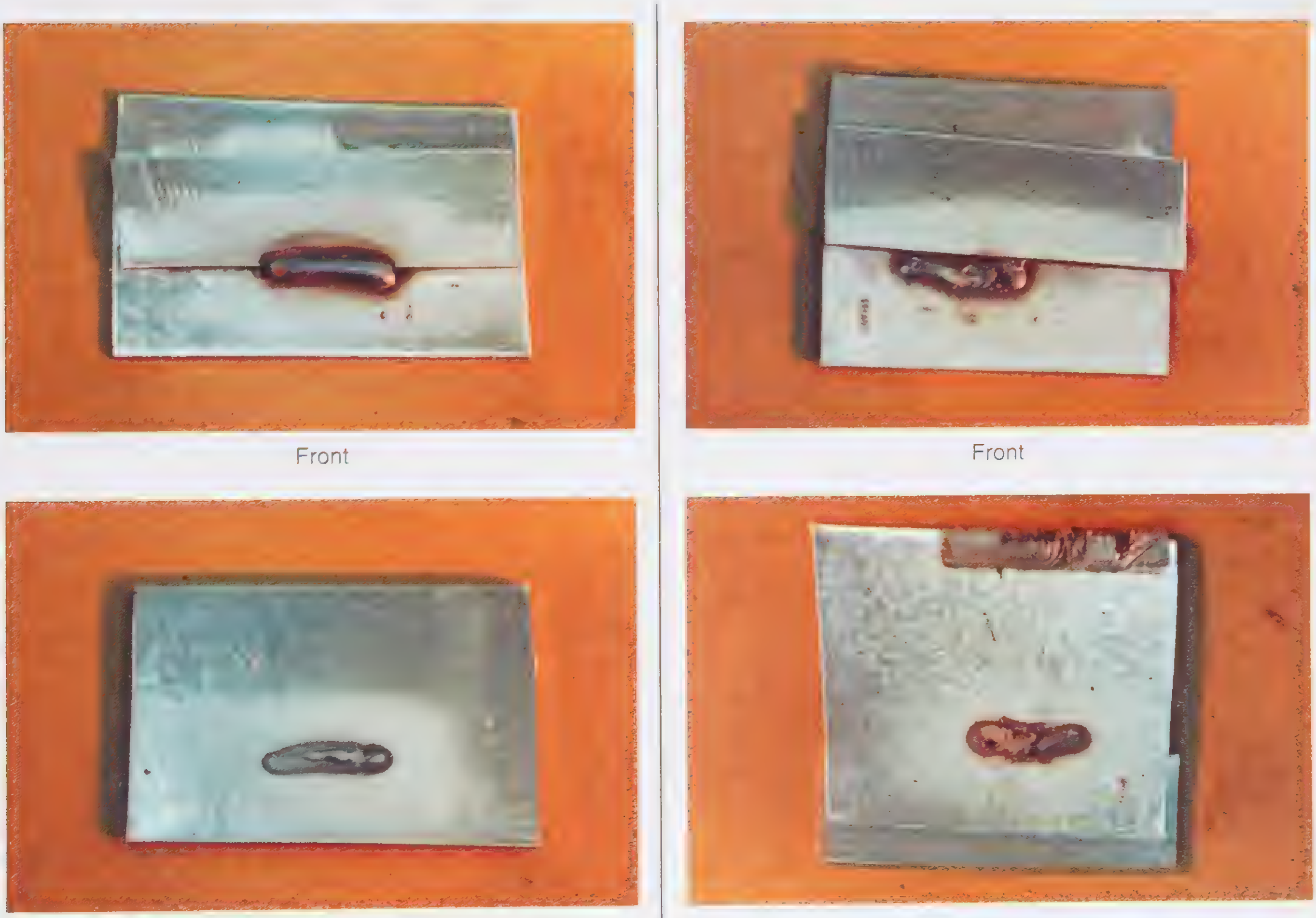
Welding metals of different thicknesses together may be required when replacing a unirail. The unirail is thicker than the surrounding metal. For example, the lower front rail is welded to the floor. When welding a thick piece of metal to a thin piece and the plug weld holes are in the thick piece, concentrate the weld on the edge of the hole. If the plug weld holes are in the thin piece, concentrate the heat on the bottom of the hole. In both cases, more heat will be applied to the thick pieces than to the thin pieces.

Stitch Weld

A stitch weld is usually made with a lap joint. To make a lap joint stitch weld, position the gun at a 60°–75° angle to the workpiece. Strike the arc and begin moving the gun. Listen for a steady buzz. A stitch weld produces enough heat to warp a panel, so be careful. Heat the upper and lower pieces equally.

The weld may be made by pushing or pulling. Pushing tends to be a little slower, giving more penetration. Do not make the weld longer than 3/4" (20 mm). Marking off 3/4" lines on the pieces may be helpful. **Figure 5-19** shows correct stitch and incorrect stitch welds.

Stitch welds can be strung together to make a continuous weld. A high-crown panel has enough strength to resist warpage, but you must be extremely careful when trying to make a continuous stitch weld on a low-crown panel. Wait for a few minutes between each weld. One method of stringing the welds together is shown in **Figure 5-20**. One stitch weld is made in the center of the panel or joint, welding to the right. The second weld is made to meet the first. The third weld starts at the edge of the first and so on.



Front

Front

Back

Back

A — Good Stitch Welds

B — Bad Stitch Welds

Figure 5-19. *A—This is a good stitch weld. Notice the heated zone visible on the top side of the weld. Ripple should be visible on the back side of the weld. B—This is a poor stitch weld. Poor welds may be weak. This weld does not follow the edge of the panel. The back of the panel shows melt through.*

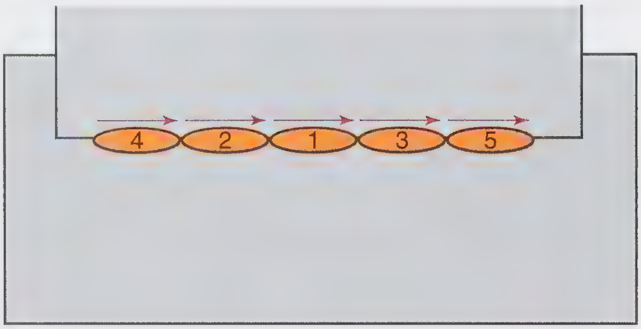


Figure 5-20. *This is one method of stringing welds together. The welds are made from left to right, starting in the center.*

Another method, which is often called ***skip welding***, is shown in **Figure 5-21**. In this method, the first weld is again made in the center of the panel or joint. The second weld is made starting 1 1/2" (3.8 cm) to the left of the first weld. The third weld is made to the right of the first weld, again starting 1 1/2" from the end of the first. Finally, the gaps are welded to form the continuous weld.

When using a stitch weld on a butt joint with an insert, the gap between the panels should be 2–4 times the thickness of one panel. A gap 4 times the thickness of the panel works best. Make the stitch weld by weaving back and forth in the gap between the panel edges. This will heat both panels and the insert for a good weld. **Figure 5-22** shows this technique.

Spot Weld

A spot weld produces a minimal amount of heat and can be used on butt joints and lap joints. Spot welds can be strung together to produce a continuous weld in the same way as stitch welds. To make a spot weld on a butt joint, position the gun at a 90° angle to one of the pieces.

The pieces should be positioned with a gap between them that is about the thickness of the metal. Pull the trigger to start the weld and then turn your wrist. Turning your wrist will bring the weld over to the other piece. The weld is made on one piece and extended to the other piece. A good butt weld, when ground down, will show no traces of panel joining.

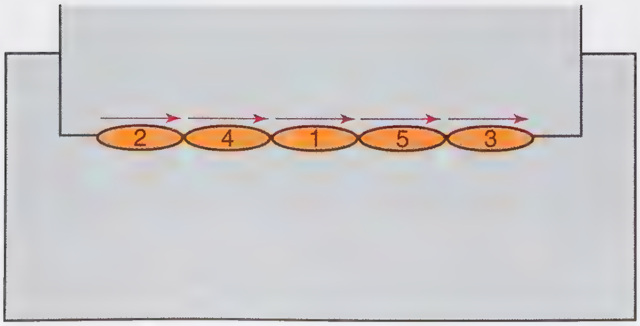


Figure 5-21. *In skip welding, the welds are also made from left to right. A gap is left between the welds to minimize heat buildup.*

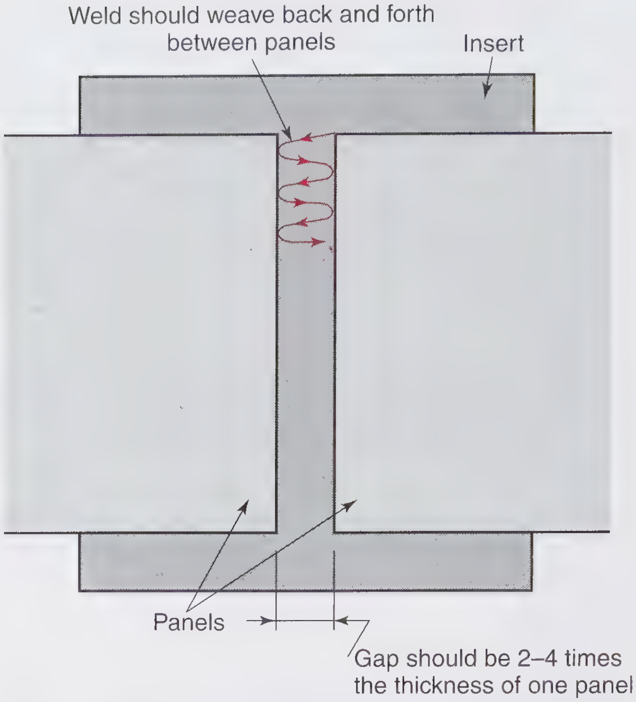

Weld should weave back and forth between panels
Insert
Panels
Gap should be 2–4 times the thickness of one panel

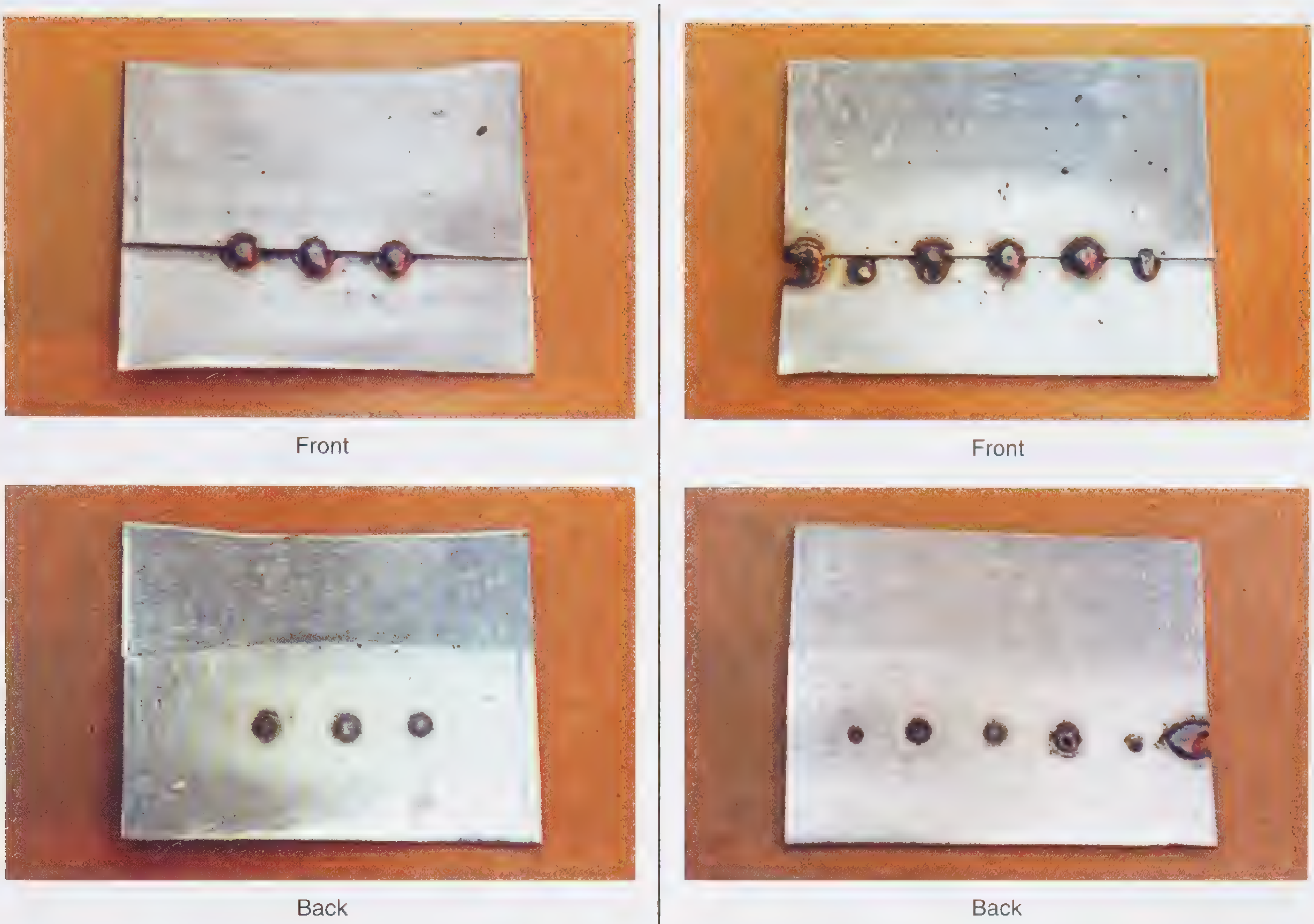
Figure 5-22. *Penetration is important when welding the gap of a butt joint with an insert. Make the stitch weld by weaving back and forth as shown here.*

If a spot weld is used on a lap or flange joint, hold the gun at a 60°–75° angle and pull the trigger for 2–3 seconds. Some technicians make a small circle with the gun while other technicians hold the gun in one place. Either method will work. **Figure 5-23** shows good and bad spot welds.

Testing Welds

Test welds should be made and examined before vehicle panels are welded. The test welds should be made on metal pieces of the same thickness as those used on the vehicle. The metal used for the test welds is usually salvaged from the damaged parts that have been removed from the vehicle. Practice making test welds on the same type of joint and in the same position that will be used on the vehicle. In fact, make each variable the same on the test weld as on the vehicle.

Test welds can be checked for strength by separating the pieces of metal. In all tests, the metal must break before the weld does. If the weld stays in place and the metal around it breaks, the weld is good. To test a single plug weld, twist the pieces in a scissors-like motion. Hydraulic force can be used to pull apart a test panel containing multiple plug welds. **Figure 5-24** shows the back of good and bad plug welds.



Front

Front

Back

Back

A — Good Spot Welds

B — Bad Spot Welds

Figure 5-23. *A—These are good spot welds. The top side is a clean, round weld bead. The back side shows a ripple. B—These are poor spot welds. The weld on the left on the top side shows burn through. The second weld on the top side has not been made at the panel edge. The back side of a poor spot weld.*

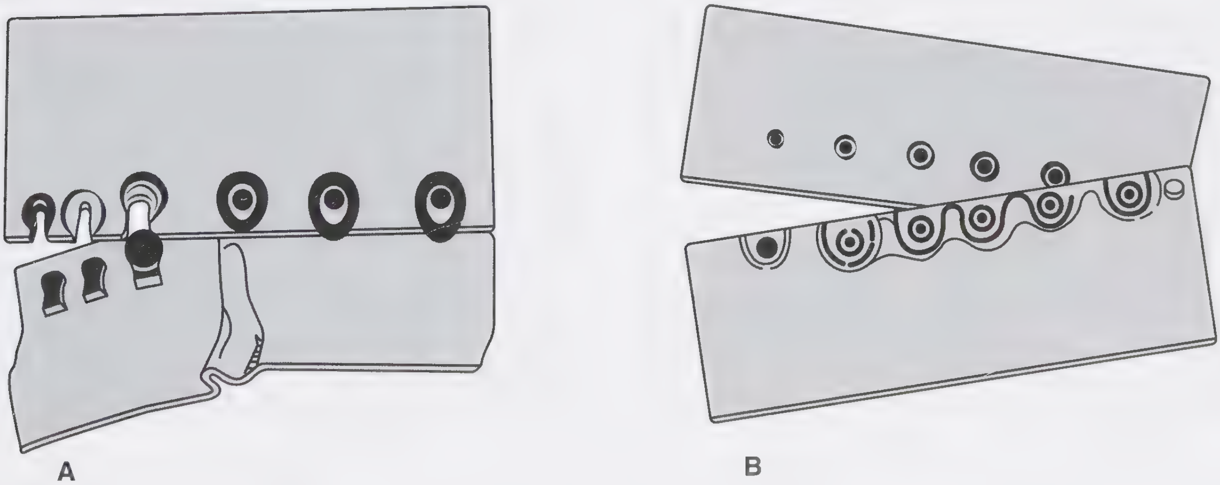


Figure 5-24. *A—A good plug weld is stronger than the surrounding metal. B—A bad plug weld is weaker than the surrounding metal.*

In a good weld, the metal will break but the weld will stay in place. In a bad weld, the weld will break loose and the metal will remain intact.

To test a stitch weld or a spot weld, place one piece in a vise and twist the other piece loose as shown in **Figure 5-25**. Both good and bad welds are shown in **Figure 5-26**.

MIG Welding Aluminum

There are currently only a few vehicles with all-aluminum unibodies. This may change in the future due to the relatively light weight of aluminum compared to steel. Aluminum is also easier to recycle than steel.

Welding aluminum is very different from welding steel. Aluminum transfers heat more readily than steel and melts at a lower temperature than steel. Steel changes color as its temperature increases. Aluminum does not.

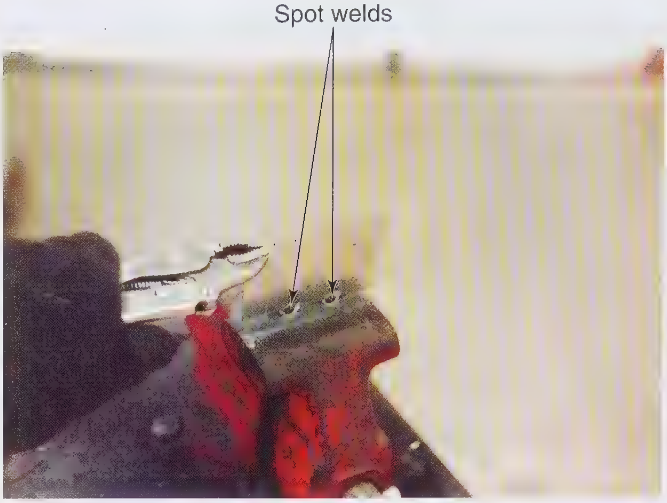


Figure 5-25. *The lap spot weld is tested by clamping one panel in a vise. Twist the other panel until the panels break apart.*

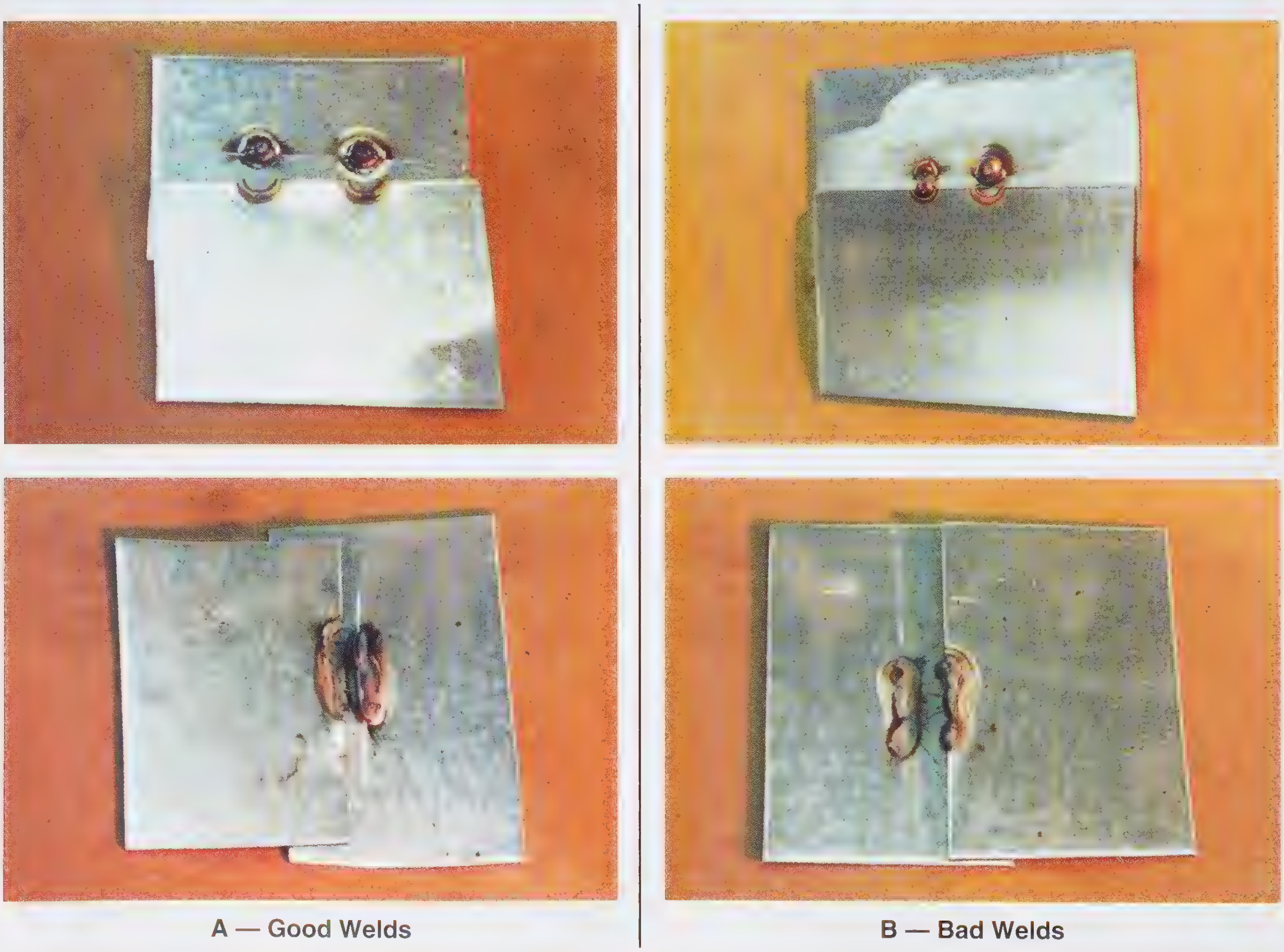


Figure 5-26. *A—Good spot welds and good stitch welds. Note that in the good welds, the metal breaks and the weld stays attached to the metal. B—If the weld breaks loose from the metal, the weld is bad.*

The MIG welding machine setup must be changed to weld aluminum. Aluminum welding wire is soft and is not easily pushed through the cable. Therefore, a push-pull wire feeder or a spool gun should be used. A ***push-pull wire feeder*** has a motor in the gun to pull the wire while the drive rollers inside the MIG welding machine push the wire. The drive rollers should be designed for aluminum. The drive rollers should be just tight enough to move the wire but not tight enough to squeeze it. A spool gun has the wire spool and drive rollers inside the gun. See **Figure 5-27**. The hose connecting the spool gun to the welder carries the gas and the electrical power, but it does not carry the wire. The welding tip should be 0.015" (0.4 mm) larger in diameter than the wire. The shielding gas used when welding aluminum can be 100% argon. Other shielding gas combinations are 50% helium and 50% argon, or 75% helium and 25% argon.

The aluminum surface must be cleaned immediately before welding. Aluminum forms an oxide layer on its surface. This aluminum oxide layer has a melting point that can be as much as 1500°F (815°C) higher than the underlying clean aluminum. Removing the oxide layer will ensure a uniform melting temperature and a good weld. Use a stainless steel brush to clean the aluminum. The brush should not be used on anything other than aluminum. If the brush contains steel particles, the particles will contaminate the aluminum. Brush gently in one direction only. Then clean the weld area with acetone.

Set the welding machine up according to a chart for aluminum welding. The correct position for holding the gun is shown in **Figure 5-28**. Gun travel speed should be faster than that for welding steel. The gun should be pushed. A travel speed that is too slow will cause melt through. Melt through occurs quickly. The aluminum will turn shiny and then melt. **Figure 5-29** shows problems that can occur in aluminum welds.

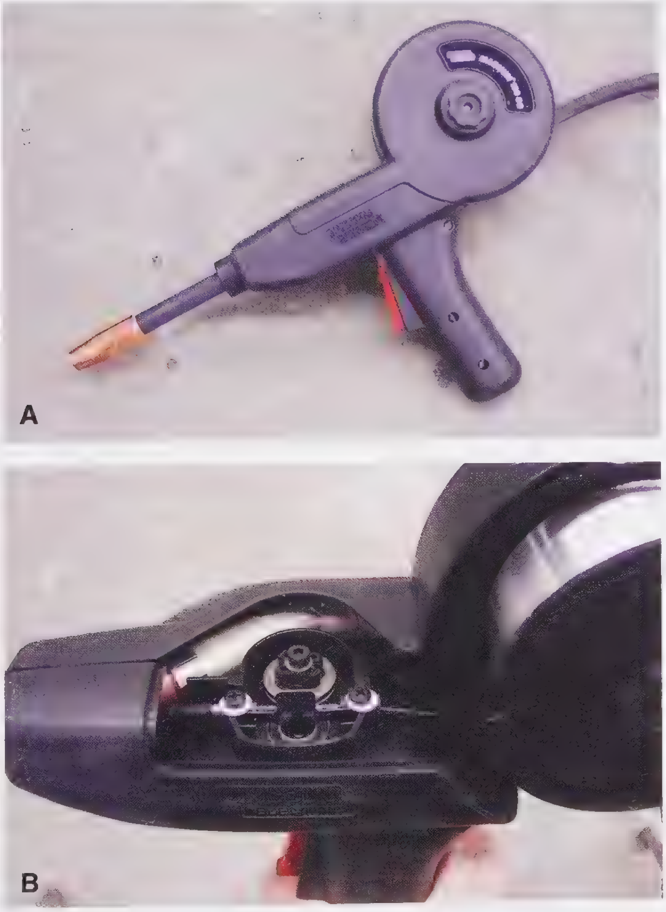


Figure 5-27. *A spool gun is often used when welding aluminum. A—Outside view of spool gun. B—View of spool gun with the cover removed, exposing the wire spool and drive rollers.*

Flux-Cored Arc Welding

Flux-cored arc welding (FCAW) is a wire-feed welding process that does not use traditional shielding gas. The FCAW welding wire is hollow. The hollow space is filled with a flux, which is burned in the arc as the welding wire melts. The burning flux produces a shielding gas that protects the weld puddle from atmospheric contamination.

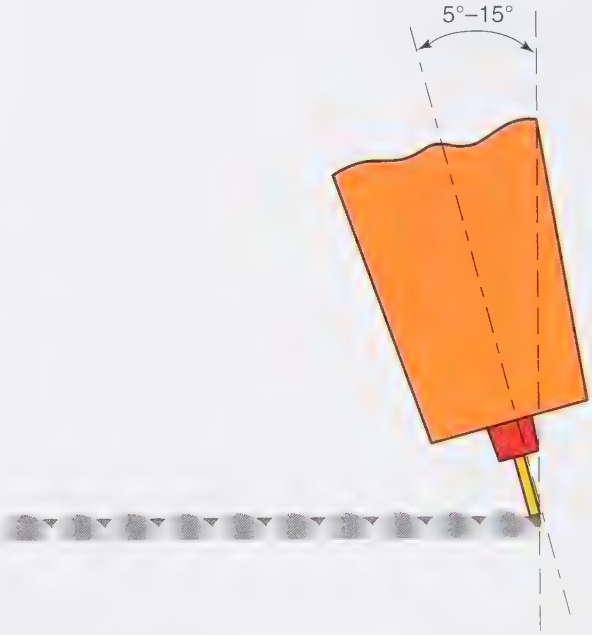


Figure 5-28. *This diagram shows the angle used to MIG weld aluminum. The gun is pushed rather than pulled.*

Aluminum Welding Defects

Defect	Main Causes
Bead crack	• Welding current too high • Improper filler metal (welding wire)
Burn through	• Welding current too high • Improper edge preparation (too wide) • Travel speed too low
Crater crack	• Improper crater treatment • Contamination • Not enough melt through
Incomplete penetration	• Improper edge preparation • Not enough welding current • Travel speed too fast • Gun angle too large
Overlap	• Not enough welding current • Travel speed too slow • Welding gun angle too small
Porosity and/or inclusions	• Use of steel wire brush • Dirt on base metal (improper cleaning) • Improper shielding (not enough shielding gas, strong wind) • Moisture, contaminants, or oxide on base metal or electrode wire
Spatter	• Worn contact tip • Arc too short • Contamination • Incorrect shielding gas or electrode wire • Improper shielding (not enough shielding gas, strong wind)
Unaligned beads	• Welding wire speed not constant • Welding gun travel speed not constant
Undercut	• Poor welding gun aim • Welding current too high • Travel speed too fast

Figure 5-29. *This table summarizes aluminum welding defects.*

FCAW cannot be used on metal thinner than 20 gauge because the smallest diameter of FCAW welding wire is 0.035". Compared to MIG welding, FCAW produces more spatter and the welds have more slag. The spatter ends up on the metal adjacent to the weld and on the MIG nozzle. ***Slag*** is contamination on the weld.

FCAW requires more precise settings on the welder and a more accurate welding gun angle than MIG welding. Some MIG welders can be converted to run FCAW welding wire by changing the drive rollers, welding cable liner, and contact tube. FCAW is of limited use in collision repair welding due to the restriction on the thickness of metal that can be welded and the clean up of spatter and slag required after welding.

Tungsten Inert Gas Welding

Tungsten inert gas welding, or ***TIG welding***, can be used on steel or aluminum. TIG welding is different from wire-feed welding in that the consumable filler material for TIG welding is a rod that is added to the weld by hand. See **Figure 5-30**. A steel filler rod is used for steel welding, and an aluminum filler rod is used for aluminum welding. The technician holds the rod in one hand and the TIG torch in the other hand. The TIG torch is connected to the power supply unit. The power supply is turned on or off by a foot pedal or by a switch on the torch. The foot pedal or switch also controls the amount of current flowing through the tungsten electrode in the torch. Current flowing through the tungsten electrode produces the arc. A burst of current is required to start the arc, and less current is needed to maintain the arc.

TIG welding uses a shielding gas dispensed from the torch to protect the weld area and filler rod from atmospheric contamination. Argon shielding gas is used when welding aluminum, and a mixture of argon and carbon dioxide is used when welding steel.

The shape and size of the tungsten electrode is critical for a good weld. Most TIG welding technicians sharpen the tungsten electrode to a clean point before each weld. The tungsten electrode must not be contaminated with steel or aluminum particles. If a bench grinder is used to sharpen the electrode, the grinding wheel should be used only for tungsten, not steel.

While current is flowing through the tungsten electrode, the electrode must not contact the metal to be welded or the filler rod. The metal or filler rod will stick to the electrode and contaminate it. A contaminated tungsten electrode will not weld properly.

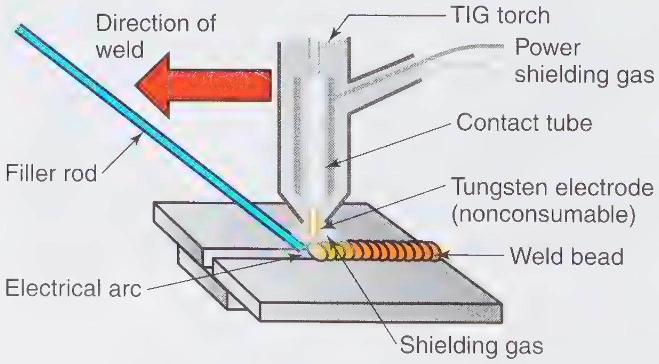


Figure 5-30. *TIG welding torch setup.*

Once the arc is started and the weld puddle is formed, the TIG torch is moved to make an overlapping series of small ovals at the weld joint. The filler rod is held within the protective envelope of the shielding gas. The filler rod is added to one end of the weld puddle as the tungsten electrode is held at the opposite end of the weld puddle. The filler rod is pulled back slightly so it will not contact the tungsten electrode as the electrode is brought around to make the oval. See **Figure 5-31**. This coordinated rotating of the torch and adding the filler is continued along the length of the weld joint.

TIG welding produces high-frequency alternating current, which can damage vehicle electronics. Therefore, TIG welds should only be made on unattached parts. For example, if a damaged aluminum part, such as a torn hood, must be TIG welded, the hood should be removed from the vehicle before welding. This will protect the vehicle from the high-frequency TIG current.

Resistance Welding

Resistance welding uses electrical current to produce enough heat to melt panels together. Electrode tips are placed against the metal panels and high current passes through the metal. The metal's resistance to the current produces heat. The heat melts the panels together at the electrodes. Once the weld cools, the panels are joined. Factory spot welds are made in this way.

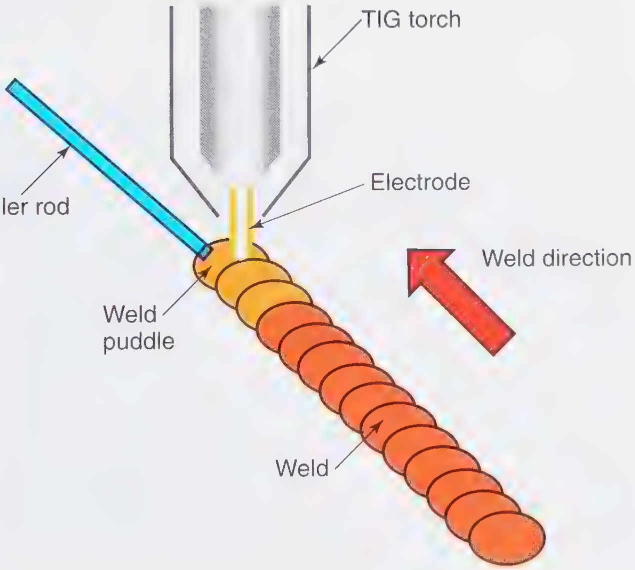


Figure 5-31. *TIG welding procedure. The filler rod is added to one end of the weld puddle as the electrode forms small overlapping ovals at the joint. The filler rod should not be allowed to touch the electrode.*

Resistance welding has several advantages over MIG welding. Because resistance welding machines produce concentrated heat, resistance welding is less likely to cause panel warpage than MIG welding. Less safety equipment is required when resistance welding. A welding helmet or #10 shade is not required for resistance welding. Additionally, resistance welding is faster than MIG welding.

There are four factors that determine the strength of a resistance weld:

- The amount of the current flow.
- The duration of the current flow.
- The amount of pressure pushing the electrodes together.
- The diameter of the electrodes.

There are two types of resistance spot welding machines available to body shops: squeeze-type resistance spot welding (STRSW) machines and panel spotters. STRSW machines are capable of duplicating factory welds in strength and appearance. Panel spotters, on the other hand, cannot duplicate factory spot welds. STRSW machines can be used to join structural parts if recommended by the manufacturer. Access to both sides of the panel is required for squeeze-type resistance spot welding, and this is not always possible. Panel thickness cannot be greater than 1/8" (3 mm) when using a STRSW machine. The arms of the machine may have to be changed to weld different shapes of panels. Panel spotters are used to join nonstructural parts or patch panels.

Weld bonding uses a combination of squeeze-type resistance spot welding and adhesive to join panels together. A bead of adhesive is applied to one panel of a lap joint. The panels are spot welded every 8" or at a distance recommended by the manufacturer. Weld bonding has the continuous joining and sealing benefits of bonding and the added strength of welding.

Squeeze-Type Resistance Spot Welding Machines

A heavy-duty squeeze-type resistance spot welding machine is shown in **Figure 5-32**. This welding machine is capable of duplicating factory spot welds and may be used on structural parts if recommended by the manufacturer.

To duplicate factory spot weld strength, the heavy-duty STRSW must generate 16,000 amps of output current. The structural STRSW must also be able to make 1/4" (6 mm) diameter spot welds between two sheets of 14-gauge steel. The diameter of the electrodes is critical. As the welder is used, the ends of electrodes will gradually increase in diameter, or mushroom. The increased size of the electrodes spreads out the welding current, leading to weaker welds.

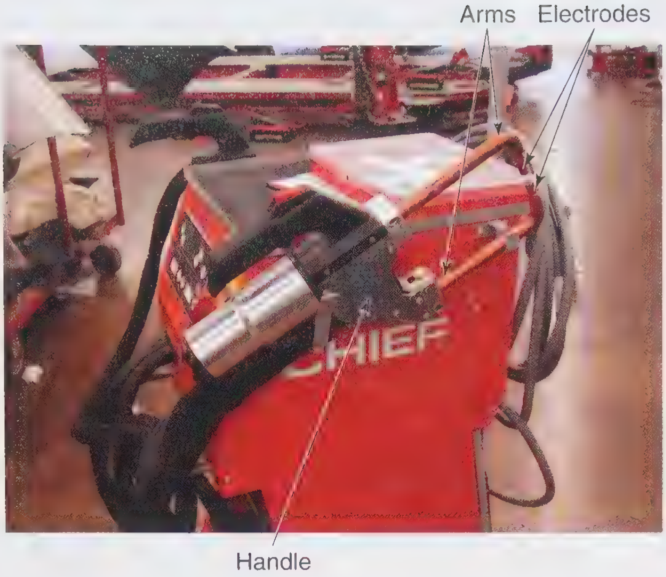


Figure 5-32. *Air pressure is used to generate the clamping force in this heavy-duty STRSW. (ProSpot)*

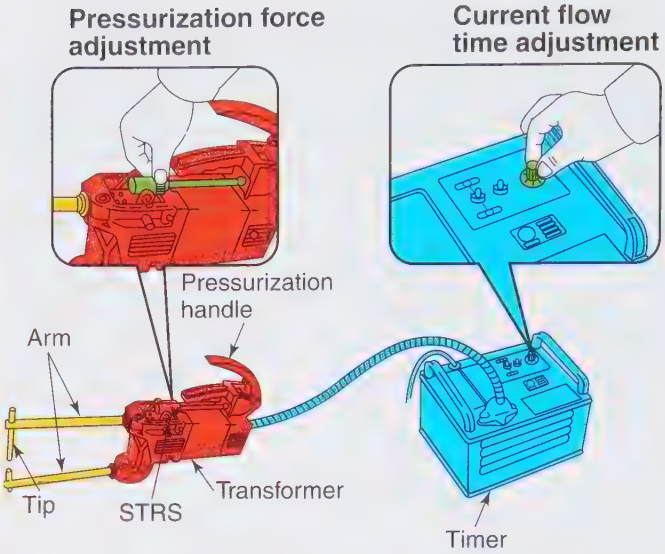


Figure 5-33. *Hand pressure produces the clamping force for this light-duty STRS. (Toyota)*

Mushroomed electrodes should be trimmed to the specified diameter before welding. The electrodes should be checked periodically and trimmed as necessary if many consecutive welds are made. A cutter is used to trim the excess width from the electrodes.

The squeeze-type resistance spot welder uses air pressure, up to 500 psi (3450 kPa), to tightly clamp the electrodes together. As in other types of welding, the panels must be held together using sheet metal screws or clamps until the welds are made. The spacing of the spot welds from each other and from the edge of the panel is critical. Thicker metals require that the spot welds be positioned farther from the edge of the panel.

A light-duty STRSW machine is shown in **Figure 5-33**. This welding machine can be used only for nonstructural welds. The welding machine is set up by adjusting the current, time, and pressure based on the metal thickness. The panels must be held tightly together with clamps or sheet metal screws. Electrode arms should be as short as possible to apply sufficient pressure. Shorter arms apply more pressure. Do not use long arms when short arms will do.

Welds should be placed between old spot welds as shown in **Figure 5-34**. One manufacturer requires 1.3 replacement welds for each factory weld. If a panel originally had 20 factory spot welds, it would require 26 replacement welds (20×1.3) to maintain structural integrity. Check the manufacturer's requirements to see if the replacement panel's E-coat should be removed before welding.

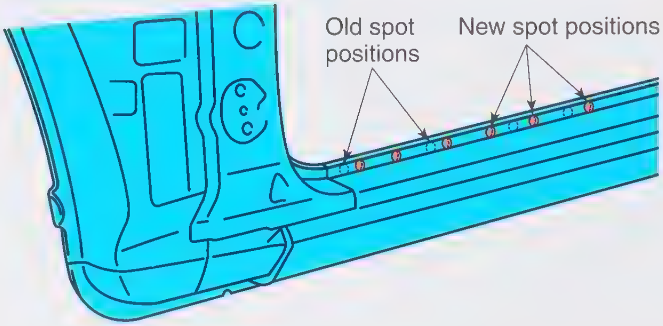


Figure 5-34. *New spot welds should be positioned between old welds. (Toyota)*

NOTE

The E-coat is the electrocoat primer applied to the panel at the factory. The electrocoating process involves applying an electric charge to a metal panel and immersing the panel in a tank of oppositely charged primer. The primer is attracted to the panel. This process forms an even, continuous film over the entire panel.

Some welding machine manufacturers want bare metal to touch bare metal. Other manufacturers may recommend that weld-through primer be applied to bare metal before welding.

If galvanizing is present, it should not be removed. Resistance spot welds can be tested in the same way as MIG spot welds. Separate the test panels. The metal should break before the weld.

Panel Spotter

A panel spotter uses two hand-held electrodes to create spot welds along lap joints. See **Figure 5-35**. The upper panel of the lap joint should be bare metal on both the top and bottom surfaces. The lower panel should be bare metal on the top surface. Weld-through primer can be applied to the bottom surface of the upper panel and the top surface of the lower panel. The electrodes are placed side to side and pressed firmly on the panel. One of the electrodes has a push-button trigger. Pulling the trigger causes current to flow through the panel, creating the weld. The panel spotter can be adjusted to control the amount of time current flows through the panel. The welds should be placed near the edge of the upper panel. If the panel joint is made at a body line, the overlap will not be as visible.

As with the STRSW, the electrode tips on the panel spotter will increase in diameter with use. The tips can be trimmed to the required 1/8" (3 mm) diameter with a pencil sharpener–like cutting tool. The 1/8" diameter tip concentrates the welding current in the proper area to produce a good, nonstructural weld. A file can also be used to keep the tips flat.

Using an Oxyacetylene Torch

An oxyacetylene torch can be used to heat steel during frame repair. The parts of an oxyacetylene setup, shown in **Figure 5-36**, are as follows:

- Acetylene tank—Portable container that stores acetylene at pressures up to 400 psi (2760 kPa). It has an on/off valve.
- Oxygen tank—Portable container used to store oxygen at pressures up to 4000 psi (27,580 kPa). It has an on/off valve.
- Acetylene regulator—Used to reduce the acetylene tank pressure to a safe working pressure that is delivered to the torch. An adjusting screw is used to set the working pressure. Gauges on the regulator show tank pressure and working pressure (pressure at the regulator's outlet). The acetylene regulator has left-handed threads on the hose outlet.
- Oxygen regulator—Used to reduce the oxygen tank pressure to a safe working pressure that is delivered to the torch. An adjusting screw is used to set the working pressure. Gauges on the regulator show tank pressure and working pressure (pressure at the regulator's outlet). The oxygen regulator has right-handed threads on the hose outlet.
- Gas hoses—Connect the regulators to the torch. The oxygen hose is green, and the acetylene hose is red. Fittings on the oxygen hose have right-hand threads, while the fittings on the acetylene hose have left-hand threads.
- Torch—Mixes the oxygen and acetylene together and directs the oxyacetylene flame to the workpiece. Control knobs are used to set the amount of each gas. In addition to the control knobs, a cutting torch has an oxygen lever, which, when pressed, releases a stream of oxygen that cuts through the metal.
- Torch tip—Gases are burned at the tip. The size of the tip's openings determines the volume of the gas released and, therefore, the amount of heat produced.

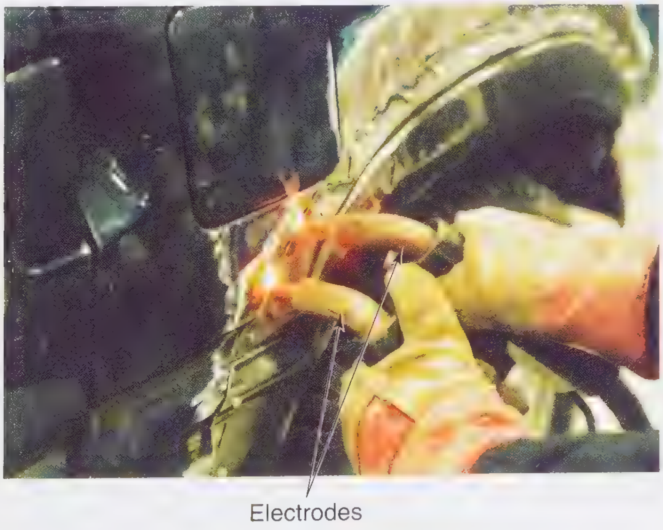


Figure 5-35. *The panel spotter electrodes are placed side by side. The technician pulls the trigger, and the electrodes weld the panels together.*

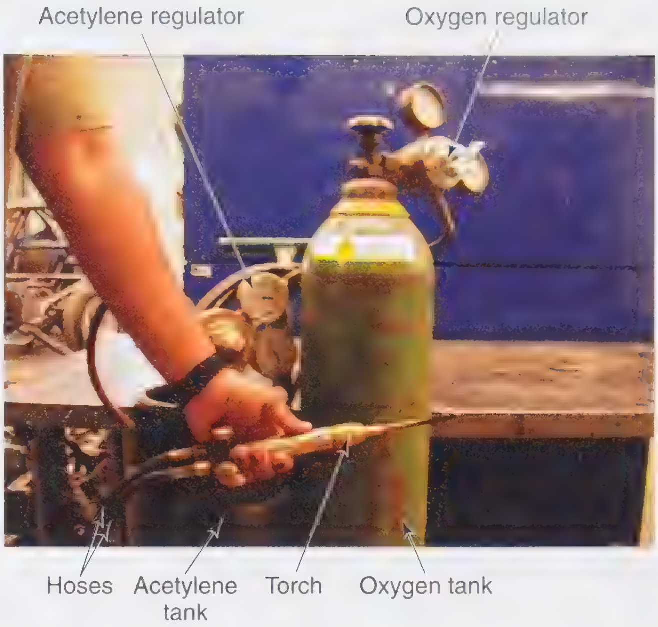


Figure 5-36. *Note the components of this oxyacetylene torch set.*

Oxyacetylene produces a flame that is bright enough to harm your eyes. Wear welding goggles. The open flame can also burn your skin. Wear long sleeves and gloves when using the torch. Remove any combustibles from the area to be heated. Do not heat near gas or brake lines. Do not set a lit torch down. Shut it off before placing it down.

Lighting an Oxyacetylene Torch

The gas regulators must be adjusted before attempting to light the torch. Make sure the regulators are closed and then slowly open the valves on the oxygen and acetylene tanks. The acetylene tank valve should be opened approximately one-quarter to one-half turn. The valve on the oxygen tank should be opened fully.

Open the acetylene valve on the torch one-half to one turn, set the acetylene regulator to the desired working pressure, and then close the acetylene valve on the torch. Next, open the oxygen valve on the torch one-half turn, set the oxygen regulator to the desired working pressure, and then close the oxygen valve on the torch. Working pressure will vary, depending on the type of torch used. Refer to the torch manufacturer's recommendations for the proper setting.

If the torch is an equal-pressure type, set the acetylene at 2 psi (14 kPa) and oxygen at 2 psi (14 kPa). If the torch is an injector type, set the acetylene at 5 psi (35 kPa) and the oxygen at 7–18 psi (48–124 kPa).

NOTE

When lighting an oxyacetylene cutting torch, open the oxygen valve *and* hold down the oxygen lever when adjusting the oxygen regulator.

After adjusting the regulators, open the torch's acetylene valve 1/16 turn. Light the torch with a spark lighter as shown in **Figure 5-37**. The burning acetylene will produce a sooty acetylene feather. Continue opening the acetylene valve until the flame no longer smokes or releases soot.

WARNING

Never use a cigarette lighter or any other open flame to light the torch.

While observing the flame, slowly open the oxygen valve and adjust the torch to achieve a neutral flame. A neutral flame is the result of a proper mixture of oxygen and acetylene. A carburizing flame results from too much acetylene, while an oxidizing flame is caused by too much oxygen. Both carburizing and oxidizing flames change the desired characteristics of steel. A carburizing flame will add carbon to metal as it heats it. An oxidizing flame forms oxide with the metal. A neutral flame adds nothing to the metal.

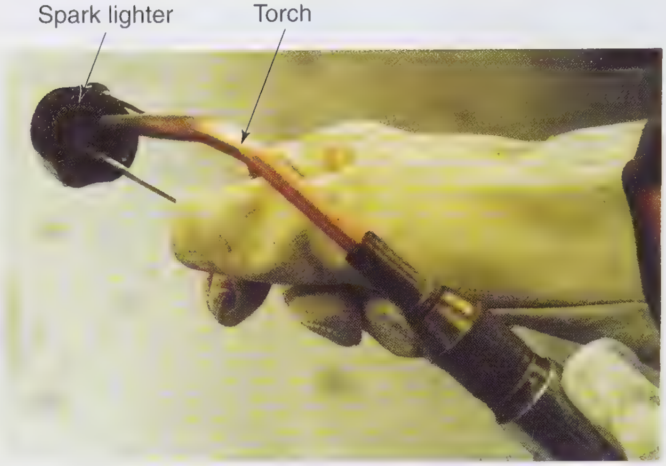


Figure 5-37. *A spark lighter should always be used to light the torch.*

NOTE

A carburizing flame is preferred for some welding, brazing, and soldering operations.

Heating Steel Parts

An oxyacetylene torch can be used to heat steel during frame repair. Use only a neutral flame for heating metal. A ***rosebud tip*** is often used to heat steel. The rosebud tip spreads out the heat of the flame, **Figure 5-38**. When heating metal, gradually warm the entire area rather than heating one area cherry red before moving on. Use a neutral flame and keep the heat as low as possible. Make sure the vehicle's manufacturer allows heating of full or unibody frames.

Temperature is critical when heating high-strength steel. Temperature can be measured with a ***temperature crayon***. The temperature crayon melts when a specified temperature has been reached. Temperature crayons are available with various melting temperatures, with 1000°F (540°C) being a good choice for vehicle repair. The crayon is either rubbed on the metal before heating for low-temperature crayons or rubbed on while the metal is hot.

The metal must be heated to a temperature that is at least one-half of the melting temperature of the crayon for the crayon to adhere to the metal. For example, if a 1000°F (540°C) crayon is used, heat the metal to at least 500°F (270°C), rub the crayon on the hot metal, then continue heating. When the crayon melts, the metal is at 1000°F (540°C). A remote-sensing infrared thermometer can also be used to determine metal temperature.

Figure 5-38. *The rosebud tip on an oxyacetylene torch can be used to heat frame components.*

Brazing

Brazing involves the use of a flux, a bronze filler rod, and an oxyacetylene torch set to a slightly carburizing flame. Both plain and flux-coated brazing rod is available. Flux-coated rod is ready to use. Plain rod, on the other hand, must be coated with flux before brazing. To apply flux to a plain rod, use the torch to heat the bottom of the rod. Then, dip the heated portion of the rod into the container of flux. The flux will adhere to the heated portion of the rod.

Brazing requires the use of both hands. The torch is held in one hand, and the filler rod is held in the other. The torch heats the base metal to a temperature below its melting point. As the metal is heated with the torch, the flux-covered bronze filler rod is placed on the metal at the joint, within the torch flame. The flux and bronze rod melt, forming a puddle. The flux cleans the metal and protects the hot brazed area from atmospheric contamination. The melted bronze puddle flows out in the joint to bond the metal pieces. The torch and bronze filler rod can be moved along to form a continuous braze. Additional flux should be applied to a bare filler rod as the rod and flux melt.

Brazed joints are not as strong as welded joints because the base metal is not melted. Grinding a brazed joint will reduce its strength. Brazing can be used to join metals that have a melting point that is greater than 1600°F (870°C), which is the melting point of the bronze filler rod. Because brazed joints are relatively weak, brazing cannot be used on any type of structural weld. Brazing can be used on nonstructural lap-joint patch panels, such as patches in fenders or doors.

Cutting Steel Parts

Steel body parts can be cut with a plasma cutter or an oxyacetylene cutting torch. High heat will weaken high-strength steel. Even low heat can warp sheet metal panels. To minimize damage, always use the least amount of heat needed to get the job done.

Using a Plasma Cutter

A plasma cutter can be used to rough cut high-strength steel panels. The panels can be final cut with a cutoff wheel or saw. A plasma cutter is shown in **Figure 5-39**. The plasma torch consists of an electrode and a nozzle. The electrode and nozzle wear slightly with every use.

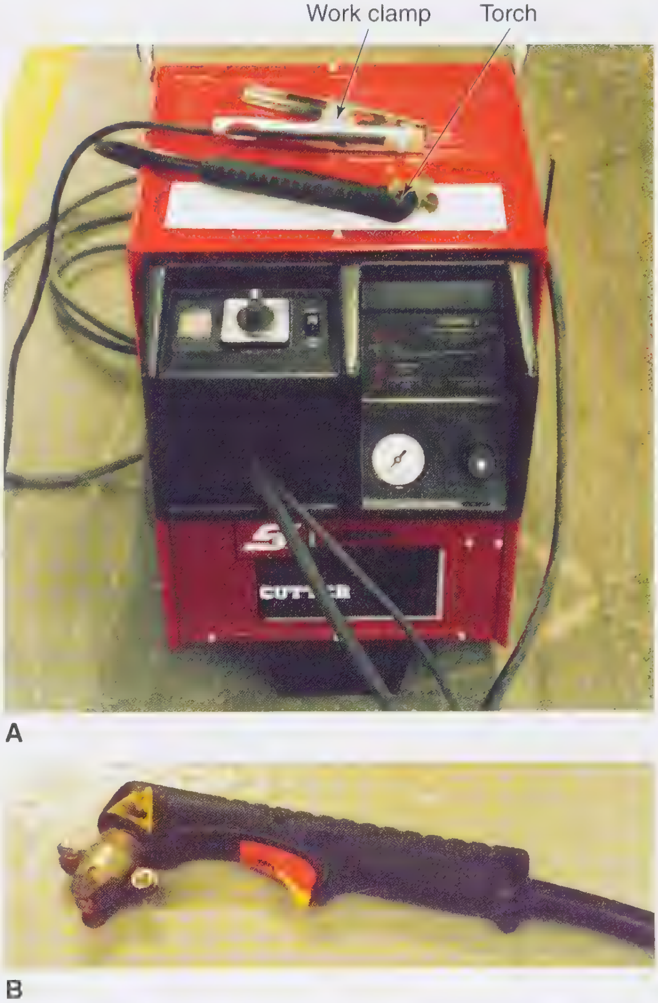


Figure 5-39. *A—A plasma cutter consists of a power source, plasma torch, and work clamp. A compressed air line is hooked up in the back of the machine. B—Close-up of the plasma torch. Notice trigger, nozzle, and electrode.*

The plasma cutter uses a stream of very hot ionized gas to cut metal. The heat is concentrated in a small area so that warpage is minimized. The plasma cutter is supplied with air from the shop's compressed air system. The electrode heats some of the air. The remainder of the air flows out of the torch as a shielding gas. The flow of air also cools the torch. The airflow may continue after cutting to cool the torch.

A plasma cutter can make a clean cut. To get a clean cut, lay out a straightedge to act as a guide while cutting because it can be difficult to make a straight freehand cut.

Plasma cutting produces sparks. Like MIG welding sparks, these can cause pits, burns, or even a fire. Protect the vehicle from sparks and remove combustibles from the work area. Always know what is behind a panel before cutting. Do not cut through wires, insulation, or lines. A welding helmet is not required when using a plasma cutter, but welding goggles or tinted face shield, welding gloves, long sleeves, and high-top boots should be worn.

To use the plasma cutter:

1. Attach the work clamp close to the cutting area.
2. Connect the compressed air line and turn on the machine.
3. Place the torch against the metal and push the trigger to start the arc.
4. Slide the torch along the metal to make the cut.

The torch does not have to be held firmly against the metal. Travel speed is determined by the metal thickness. Sheet metal is easily cut and rapid torch movement is required. However, moving too fast will result in partial cuts. Moving too slow will cause the arc to shut off. If the arc does shut off, air will continue to flow from the torch. Allow the air stream to shut off before attempting to cut again. A well-made plasma cut is uniform in width and straight. A poor cut may not penetrate completely, or it may be jagged and nonuniform in width. See **Figure 5-40**.

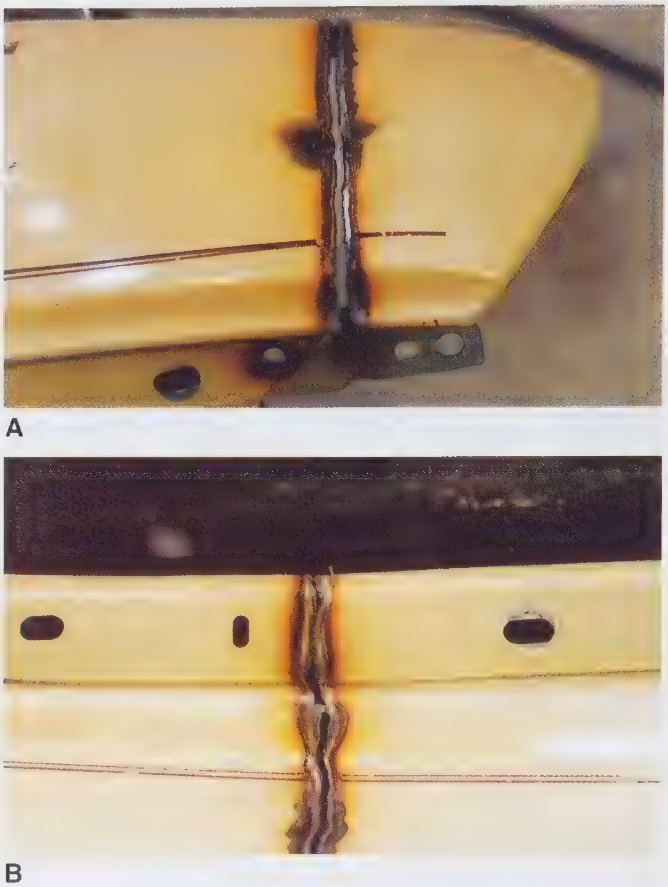


Figure 5-40. *A—A good plasma cut is smooth and completely separates the panels. B—This poor plasma cut has a gap where the metal is still joined. The cut is also too jagged.*

Using an Oxyacetylene Cutting Torch

If an oxyacetylene cutting torch is used to rough cut high-strength steel, the metal within 2" (50 mm) of the rough cut should be final cut using a saw or cutoff wheel. The high-strength steel grains within the 2" range of the oxyacetylene cut will be overheated and weakened. An oxyacetylene cutting torch is shown in **Figure 5-41**. The torch burns oxygen and acetylene to produce enough heat to melt steel. It can also be used to cut off rusted bolts. The torch has a lever to add oxygen into the flame. Welding goggles, a face shield, gloves, a cap, and long sleeves must be worn when using the torch.

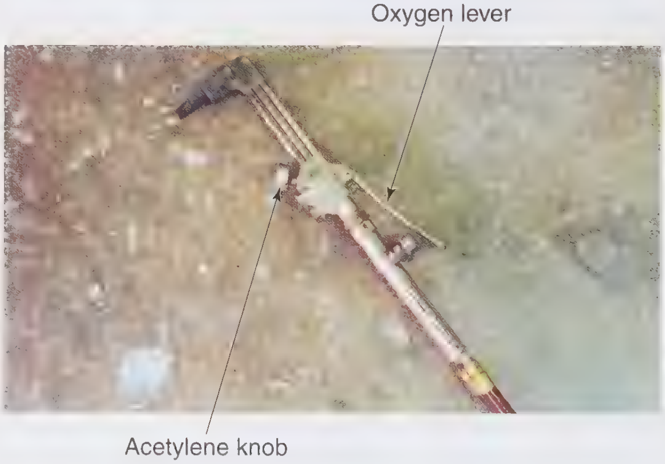
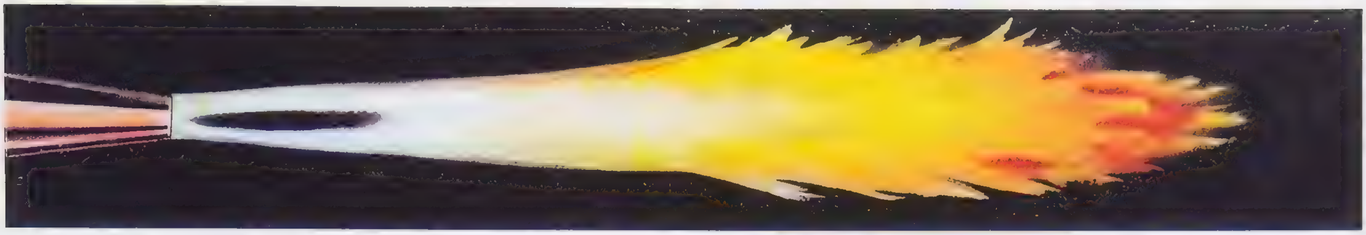
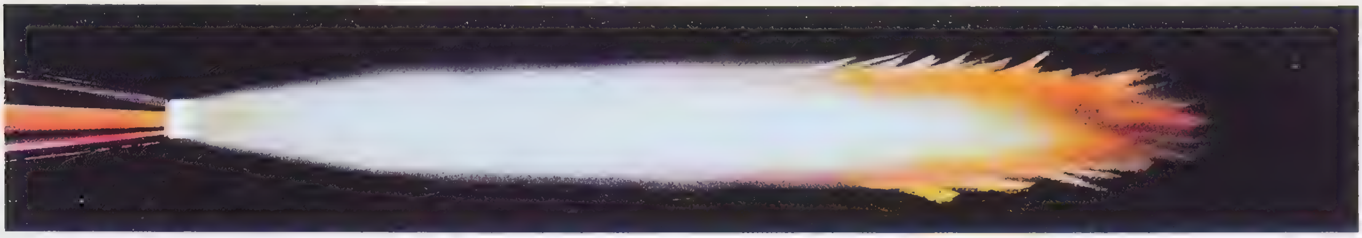


Figure 5-41. *Pressing the oxygen lever on this oxyacetylene torch adds additional oxygen to the flame.*

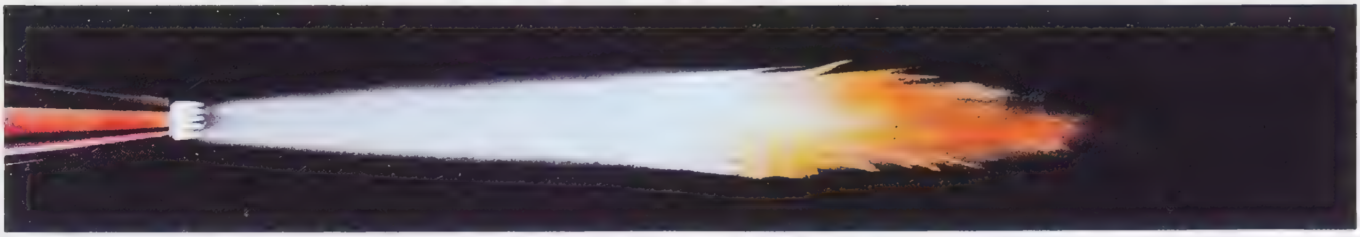
Set the acetylene regulator to 5 psi (35 kPa) and the oxygen regulator to 15 psi (103 kPa). Crack open the acetylene knob on the torch and light the torch. Add in oxygen to get a neutral flame. See **Figure 5-42**. Heat the area to be cut with the points of the flame. Once the area is warm, press the oxygen lever. Start at one edge of the workpiece and cut through the part. As with plasma cutting, know what is behind and around the part before cutting.



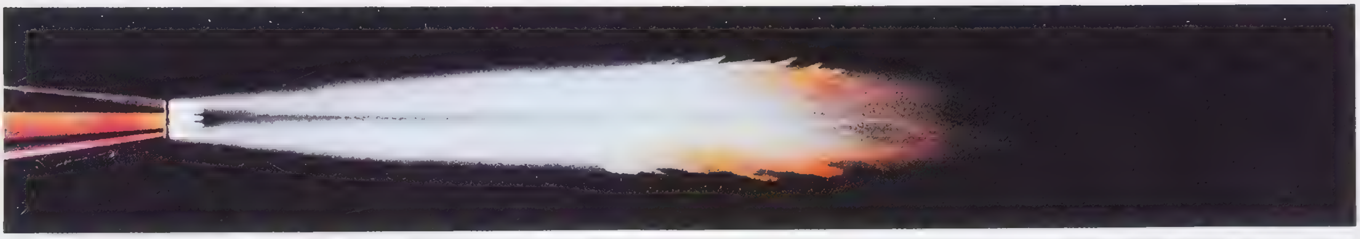
Acetylene Burning in Atmosphere
Open fuel gas valve until smoke clears from flame.



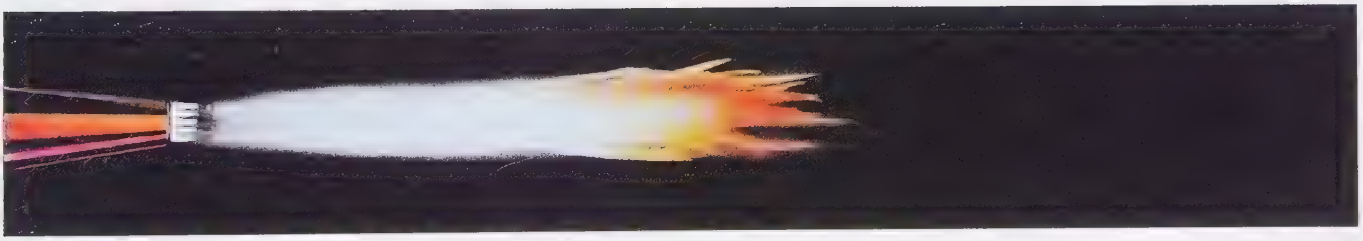
Carburizing Flame
(Excess acetylene with oxygen.) Preheat flames require more oxygen.



Neutral Flame
(Acetylene with oxygen.) Temperature 5589°F (3087°C). Proper preheat adjustment for cutting.



Neutral Flame with Cutting Jet Open
Cutting jet must be straight and clean.



Oxidizing Flame
(Acetylene with excess oxygen.) Not recommended for average cutting.

Figure 5-42. *These are the five types of oxyacetylene cutting flames.*

Summary

- Always observe safety rules when welding. Protect the technician, vehicle, co-workers, and shop.
- The parts of the MIG welding machine that require adjustment are the drive roller tension spring, the gas regulator, the voltage setting, and the amps setting.
- When MIG welding, balance the amp setting and the voltage setting to produce a stable arc.
- Welding variables are wire diameter, amp setting, voltage setting, weld type, orientation, fit up, preparation, galvanizing, gas orientation, travel speed, travel direction, and stick out.
- The types of welds are stitch, plug, and spot.
- The MIG welding machine should produce a steady buzz and steady light when welding properly.
- Practice welds should be made and tested before welding on the vehicle.
- Welding aluminum is much different from welding steel.
- STRSW may be used to replace factory spot welds on structural panels.
- Plasma cutting can produce a clean cut edge.
- A cutting torch should only be used to cut off bolts or salvage parts.

Review Questions

Please do not write in this textbook. Place your answers on a separate sheet of paper.

1. A(n) ______ helmet changes from clear to shaded as soon as the arc is struck.
2. It is a good idea to stop welding about an hour before the end of the workday. True or False?
3. A MIG welding machine can be plugged into a light-duty extension cord. True or False?
4. In a(n) ______ joint with a(n) ______, two panels are aligned edge to edge and another piece is positioned below the joint to connect the panels.
5. In a(n) ______ joint, one panel is placed on top of the other panel.
6. Poor fit up can lead to melt through. True or False?
7. What is the purpose of weld-through primer.
8. Define the term *arc*.
9. The area of molten wire and metal caused by the heat of the MIG welding arc is known as the ______.
10. The shielding gas for MIG welding steel is ______% argon and ______% carbon dioxide.
11. MIG welding with ______ wire does not require a shielding gas.
12. To MIG weld galvanized steel, set the volts and amps slightly lower than normal. True or False?
13. Define the term *stick out*.
14. Describe *skip welding*.
15. Explain how to test a plug weld.
16. Why is it important to clean aluminum oxide from the surface of aluminum just before MIG welding?
17. A heavy-duty ______ welding machine is capable of reproducing factory spot welds.
18. What type of oxyacetylene flame adds nothing to the metal?
19. When heating metal with an oxyacetylene torch, you should gradually warm the area to be heated. True or False?
20. Because the heat of the plasma cutter is concentrated in a small area, ______ is minimized.

ASE-Type Questions

1. Technician A says that most collision repair welding is done in such a way that it minimizes heat buildup. Technician B says that excessive heat weakens high-strength steel. Who is right?
   (A) A only.
   (B) B only.
   (C) Both A and B.
   (D) Neither A nor B.
2. Technician A says that a spot weld is made by striking an arc and moving the gun a short distance. Technician B says that plug welds are used to duplicate factory spot welds on structural parts. Who is right?
   (A) A only.
   (B) B only.
   (C) Both A and B.
   (D) Neither A nor B.
3. Each of the following statements about lap joints is true EXCEPT:
   (A) one panel is placed on top of the other to form the joint.
   (B) a flange can be made in one of the panels so they will be flush after welding.
   (C) plug welds can be used to weld the joint together.
   (D) an insert is placed below the joint to connect the panels.
4. Each of the following is part of the wire feeder EXCEPT:
   (A) drive rollers.
   (B) tension spring.
   (C) work clamp.
   (D) spool.

5. MIG welding a vertical panel is being discussed. Technician A says most welds are made in the vertical up direction. Technician B says most welds are made in the vertical down direction. Who is right?
   (A) A only.
   (B) B only.
   (C) Both A and B.
   (D) Neither A nor B.
6. Stick out on a MIG welding machine is being discussed. Technician A says that with 0.023" wire, the stick out should be at least 1/4" but not more than 3/8". Technician B says that stick out is the distance between the welding tip and the panel. Who is right?
   (A) A only.
   (B) B only.
   (C) Both A and B.
   (D) Neither A nor B.
7. A standard plug weld hole for collision repair work is which size?
   (A) 3/16".
   (B) 1/4".
   (C) 5/16".
   (D) 3/8".
8. When making a plug weld, Technician A holds the gun at 45° to the workpiece. Technician B aligns the welding wire so it touches the bottom piece of metal and the edge of the hole, and then welds all the way around the perimeter of the hole. Who is right?
   (A) A only.
   (B) B only.
   (C) Both A and B.
   (D) Neither A nor B.
9. Three panels must be welded in a lap joint. Technician A says that the plug hole in the upper panel should be smaller than the plug hole in the middle panel. Technician B says that the plug hole in the bottom panel should be the largest. Who is right?
   (A) A only.
   (B) B only.
   (C) Both A and B.
   (D) Neither A nor B.
10. When making stitch welds on a lap joint, the MIG gun should be held at a(n) ______ angle.
   (A) 90°
   (B) 80°
   (C) 60°
   (D) 45°
11. A lap joint in a low-crown panel must be welded. Technician A wants to use skip welding along the joint. Technician B says that waiting between welds is not necessary when welding a low-crown panel. Who is right?
   (A) A only.
   (B) B only.
   (C) Both A and B.
   (D) Neither A nor B.
12. A butt joint with an insert is being stitch welded. Technician A says that there should be no gap between the panels. Technician B says that the gap between the panels should be the same as the thickness of one of the panels. Who is right?
   (A) A only.
   (B) B only.
   (C) Both A and B.
   (D) Neither A nor B.
13. Which of the following statements about welding aluminum with a MIG welding machine is true?
   (A) The travel speed is slower.
   (B) The aluminum will change color with increasing temperature.
   (C) A push-pull wire feeder should be used.
   (D) The aluminum does not require cleaning prior to welding.
14. Which of the following welds uses adhesives?
   (A) Stitch weld.
   (B) Butt weld.
   (C) Weld bonding.
   (D) Butt joint with insert.
15. All of the following are factors that determine the strength of a STRSW EXCEPT:
   (A) electrode diameter.
   (B) amount of current flow.
   (C) thickness of the metal.
   (D) duration of current flow.
16. When using a STRSW, Technician A says that the welding machine clamping force is all that is required to hold the panels together. Technician B says that the panels should be held together with clamps or screws in addition to welding machine clamping force. Who is right?
   (A) A only.
   (B) B only.
   (C) Both A and B.
   (D) Neither A nor B.
17. A panel will be welded with a heavy-duty STRSW. Technician A wants to grind the galvanized coating from the replacement panel. Technician B says that the electrode arms should be as long as possible. Who is right?
   (A) A only.
   (B) B only.
   (C) Both A and B.
   (D) Neither A nor B.

18. Oxyacetylene gas hoses are being discussed. Technician A says the fittings on the oxygen hose have left-hand threads. Technician B says the fittings on the acetylene hose have right-hand threads. Who is right?
    (A) A only.
    (B) B only.
    (C) Both A and B.
    (D) Neither A nor B.
19. All of the following should be worn as safety equipment when plasma cutting EXCEPT:
    (A) a welding helmet.
    (B) safety glasses.
    (C) welding gloves.
    (D) long sleeves.
20. When plasma cutting metal, the travel speed will depend on the ______.
    (A) air temperature
    (B) thickness of the metal
    (C) air pressure supplied to the plasma cutter
    (D) plasma cutter's duty cycle

Chapter 6

General-Purpose Tools and Equipment, Service Information

Objectives

After studying this chapter, you will be able to:

- Identify and describe the general-purpose hand tools used by the collision repair technician.
- Identify and demonstrate the use of the power tools used by the collision repair technician.
- Describe the various types of shop equipment encountered in the collision repair shop.
- Demonstrate the safe use of floor jacks, jack stands, and lifts.
- Identify and explain the use of the service information found in the collision repair shop.

Technical Terms

air ratchet
blind rivets
chisels
compressed air system
creeper
drill bits
drills
floor jack
hacksaw
hammers
impact wrench
jack stands
lifts
MIG welder
pilot hole
pliers
pry bars
punches
rivet gun
scrapers
screwdrivers
service cart
service information
snips
tap and die set
toolbox
torque wrenches
upholstery removal tools
utility knife
wrenches

Introduction

A collision repair technician is expected to have a complete set of tools. Most technicians invest thousands of dollars in tools. Acquiring tools is usually a continuous process. Even technicians with twenty year's of experience and a vast tool collection must replace worn or outdated tools. As an entry-level technician, you should possess a basic tool collection.

Tools are generally available in three grades: professional, hobbyist, and homeowner. Professional-grade hand tools have a lifetime warranty. If the tool breaks, the manufacturer will replace it at no charge. Professional tools are often sold by company representatives who make weekly sales calls on automotive repair shops. These representatives sometimes arrange financing for the purchase of the tools and collect weekly payments. They also replace damaged tools that are covered under warranty. Professional-grade tools may be available on the Internet. Many specialty auto body tools are available only as professional-grade tools and are not sold to the general public.

Like professional-grade tools, hobbyist hand tools often have a lifetime warranty. Hobbyist tools are available from retailers and over the Internet. Some hobbyist specialty tools are available from companies that cater to the auto restoration hobbyist.

Homeowner tools do not have a lifetime warranty and are not intended for daily use. A collision repair technician should never buy these types of tools for use on the job, as they will fail when subjected to rigorous use.

The value of a tool is in how well it does the job and how long is lasts. Professional-grade tools cost more—sometimes surprisingly more—than hobbyist tools. Keep in mind, however, that the most expensive tool is not always the best choice. The increased cost may not justify the purchase of a professional-grade tool if the tool will not be used on a regular basis.

Whatever grade of tools you buy, always use and maintain them properly. Do not use a tool to do a job for which it was not designed. For example, never use a standard (flat-blade) screwdriver to do the job of a chisel or pry bar. Do not overstrain a tool. If you slip a pipe over a ratchet to apply extra leverage when removing a fastener, you may break the ratchet. Keep your tools clean and dry. Wipe grease and dirt from your tools at the end of each job. Store your tools in an orderly manner in a dry environment. Take care of your tools and they will last a lifetime.

Tool Storage

To work efficiently, collision repair technicians should keep their tools clean and well organized. A ***toolbox*** is used to store and organize tools. It also protects tools when they are not being used. There are two styles of toolboxes: chest-and-cabinet toolboxes and workbench toolboxes. Chest-and-cabinet toolboxes are the most common type. As shown in **Figure 6-1**, they consist of a cabinet that is mounted on wheels and a chest that is mounted on the cabinet. The entire unit can be moved around as required. The number of drawers varies from one model to another. The size of the drawers, as well as the width, depth, and height of the toolbox, also depends on model type. Both the chest and the cabinet should have locks to prevent tools from being stolen.

A workbench-style toolbox, **Figure 6-2**, has a durable wood or stainless steel work surface. This surface is useful for assembling components and staging tools. This type of toolbox is mounted on wheels so it can be moved to the work area. There are a variety of drawer arrangements available.

When choosing a toolbox, remember that many body tools, such as power sanders and slide hammers, are bulky. There should be at least one drawer that is deep enough to hold these large tools.

To maintain a toolbox, keep it out of moist areas. Oil the drawer slides and wheels if specified by the manufacturer. To prevent the toolbox from tipping, never open more than one drawer at a time. This is particularly important on tall chests and cabinets.

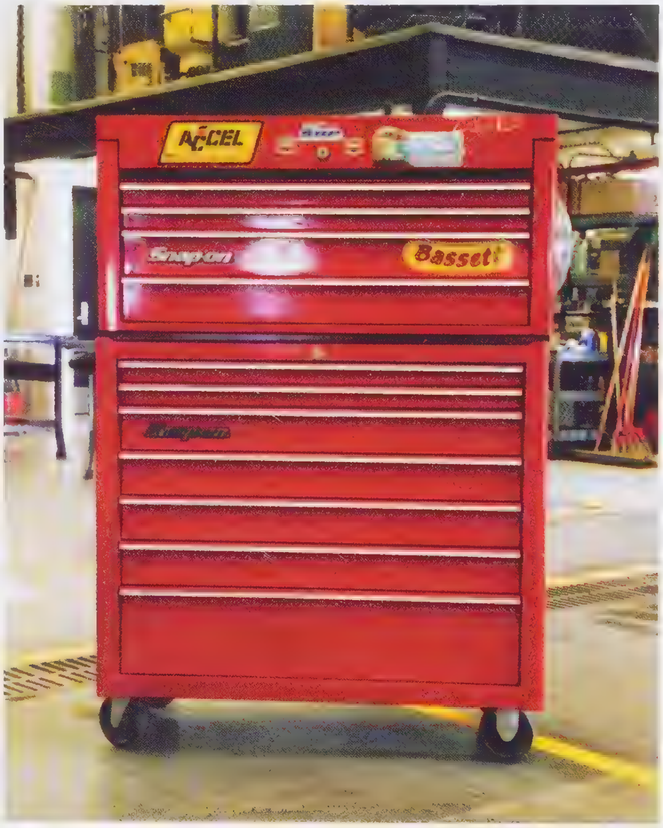


Figure 6-1. *A chest-and-cabinet toolbox can be used to store and move tools.*

MAC TOOLS
TECH 1000
MAC TOOLS

Figure 6-2. *This workbench-style toolbox has a hardwood work surface that can be used as a workbench.*

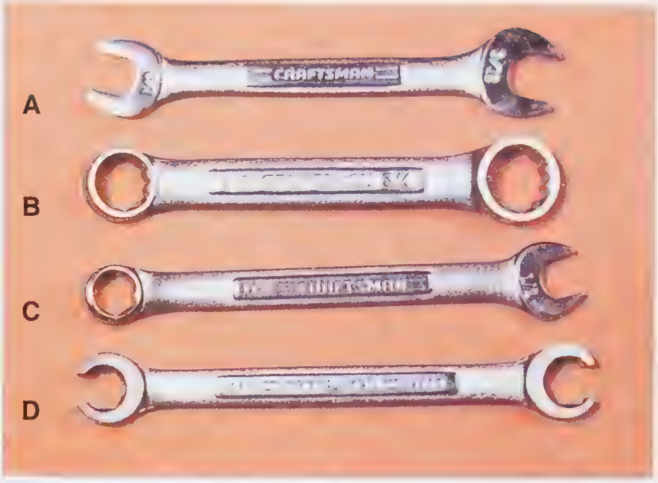


Figure 6-3. *A variety of wrenches are used by the collision repair technician. A—Open-end wrench. B—Box-end wrench. C—Combination wrench. D—Tubing wrench.*

General-Purpose Hand Tools

There are a variety of general-purpose hand tools used by the collision repair technician. These tools can be used for many collision repair tasks, as well as common mechanical repairs.

Wrenches

Wrenches are used to tighten or loosen nuts and bolts. The size of a wrench is determined by the width of its opening. Both standard and metric wrenches are available. Wrenches are available in a variety of configurations. See **Figure 6-3**. Typical wrenches used by the collision repair technician include the open-end wrench, the box-end wrench, and the combination wrench.

The open-end wrench has a U-shaped opening that grips the head of the fastener on two sides. This type of wrench has a different-size opening on each end. A box-end wrench, on the other hand, completely surrounds the fastener. This reduces the possibility of the wrench slipping from the fastener. Like the open-end wrench, each end of a box-end wrench is a different size. Box-end wrenches can have 6- or 12-point openings. Wrenches with six-point openings are less likely to slip and damage the fasteners than those with 12-point openings. However, a wrench with a 12-point opening can be positioned in twice as many places on the fastener, which is beneficial in locations where swing is limited. Some wrenches combine a box-end head with ratcheting action, which allows a fastener to be tightened or loosened without removing the wrench from the fastener.

Combination wrenches have an open end and a box end. Both ends of a combination wrench fit the same size fastener. As its name implies, an offset wrench has a head that is offset from the handle to help keep the operator's hands away from the work surface. See **Figure 6-4**.

A tubing wrench, or line wrench, is used to loosen and tighten fittings. This type of wrench is similar to a box-end wrench, but it has a small opening that allows it to be slipped over lines and onto the fitting nut. Because the tubing wrench surrounds more of the fitting than an open-end wrench, it is less likely to slip and cause fitting damage.

Socket wrenches consist of a drive handle and a set of interchangeable sockets. The sockets surround and grip the nut or bolt to be tightened or loosened. The drive handle is used to turn sockets. See **Figure 6-5**.

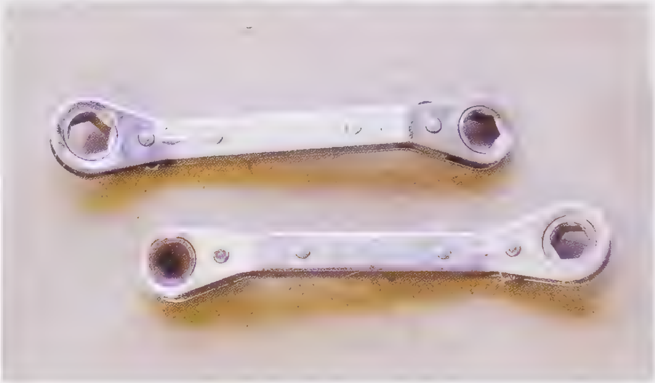


Figure 6-4. *Offset wrenches help keep hands out of harm's way.*

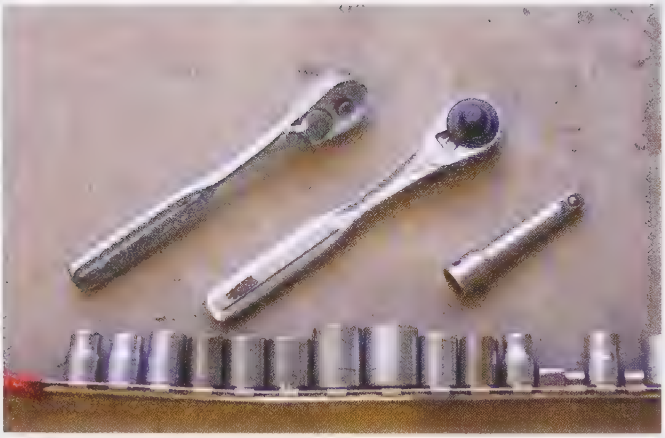


Figure 6-5. *The two sides of a 3/8"-drive ratchet are shown with an extension and various sockets.*

A variety of sockets are shown in **Figure 6-6**. Deep-well sockets are designed to reach a nut securing a protruding bolt. However, deep sockets can pivot while turning, twisting the ratchet out of your hand. Therefore, it is best to use the shortest socket that will do the job.

Sockets have an opening on each end. One opening is square and fits onto the drive handle. The size of the square opening is referred to as the socket's drive size. Sockets are available in 1/4", 3/8", and 1/2" drive sizes. The other opening fits over the fastener. This opening will have either six or twelve points. Six-point sockets are less likely to slip from the fasteners than twelve-point sockets. Sockets are available in both metric and standard sizes.

CAUTION

Inspect sockets for wear. If the points are rounded, the socket will not grip the fastener properly. It may slip off or damage the corners of the fastener.

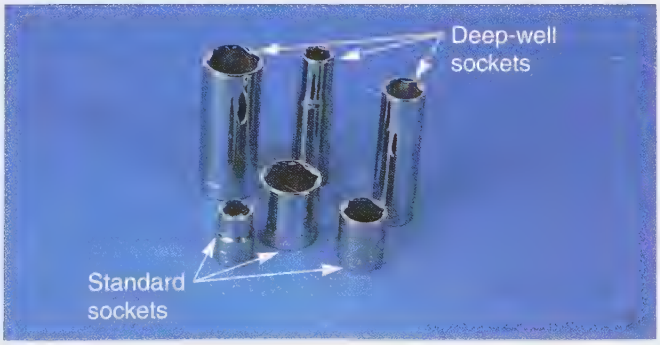


Figure 6-6. *Deep-well sockets are longer than standard sockets, providing extra clearance needed to reach some fasteners.*

Some components, such as seat belt anchors, are held in place with torx head fasteners. Torx sockets, which are used to remove these fasteners, are shown in **Figure 6-7**. The common sizes of torx sockets are T-10 through T-50, with smaller numbers indicating smaller sizes. When using a torx socket, make sure that it is the proper size. A proper size torx socket will completely fill the opening in the fastener. A torx socket that fits loosely in the fastener may slip out of the opening when it is turned.

NOTE

Small torx head fasteners are removed or installed with torx screwdrivers. These will be discussed later in this chapter.

Drive handles include the ratchet handle, the breaker bar, the speed handle, and the T-handle. See **Figure 6-8**. The drive handle most commonly used in the collision repair shop is the ratchet handle, or ratchet. The ratchet, Figure 6-8A, allows you to loosen or tighten a fastener without removing the socket from the fastener. Moving a lever on the ratchet's head changes the direction of socket rotation. To install a fastener, the lever is positioned so the ratchet locks when it is turned clockwise and releases when it is turned counterclockwise. When the lever is moved to the opposite position, the ratchet locks when turned counterclockwise and releases when turned counterclockwise. Some ratchets have an oil hole for lubrication.

Ratchets are available in many different sizes. They can have a 1/4", 3/8", or 1/2" drive (portion that fits into the socket). Ratchet handles can be long or short. The longer the ratchet handle, the more torque it can apply to the fastener. Some ratchets have a pivoting head that allows them to be used in confined areas.

The breaker bar, Figure 6-8B, provides extra leverage for removing stubborn fasteners. The speed handle, Figure 6-8C, allows fasteners to be turned more quickly than with other drive handles. The T-handle can be used to remove fasteners in tight spaces. See Figure 6-8D.

Extensions can be used with sockets and drive handles when removing fasteners that are relatively far

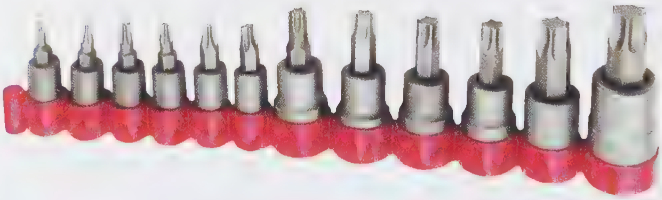


Figure 6-7. *Torx sockets are used to remove or install Torx-head screws or bolts.*

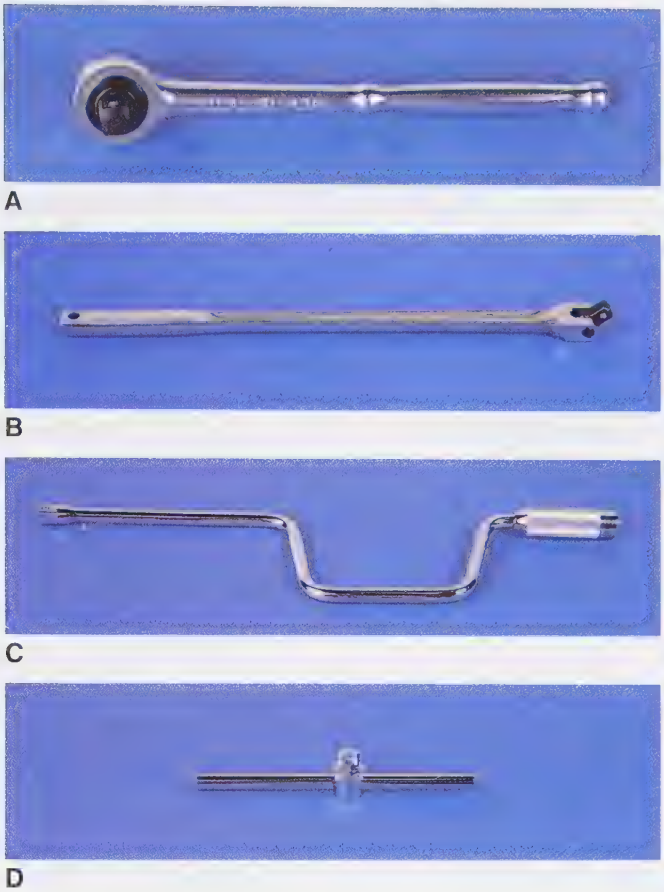


Figure 6-8. *Drive handles. A—Ratchet. B—Breaker bar. C—Speed handle. D—T-handle.*

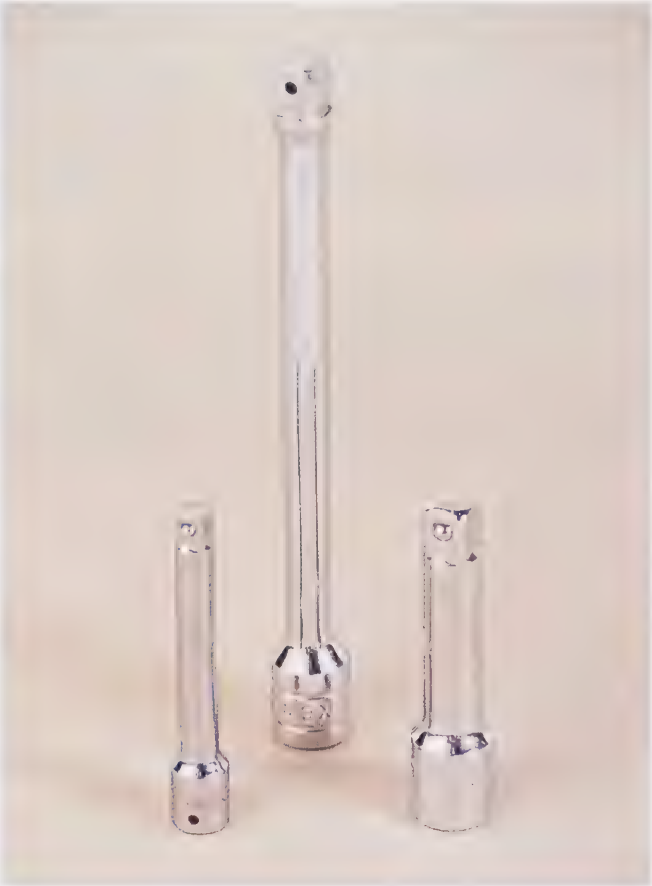


Figure 6-9. *Extensions allow a socket to be used in obstructed or distant areas.*

from the drive handle. **Figure 6-9** shows extensions of different lengths. An extension is placed between the ratchet and the socket. The increased distance between the socket and drive handle allows the socket to reach a fastener, even if the fastener is several inches away from the handle.

Torque wrenches are used to tighten bolts and nuts to specific torque specifications. The torque specifications for various fasteners can generally be found in the vehicle manufacturer's service information. Torque specifications are given in either foot pounds (ft lb) or Newton meters (N·m).

Pliers

Pliers are designed to grip or cut various objects. They should never be used in place of a wrench to remove nuts, bolts, or fittings, as they tend to damage fasteners. There are many different types of pliers used in collision repair. See **Figure 6-10**.

Combination slip-joint pliers, Figure 6-10A, are commonly used in the collision repair shop. The slip joint allows the width of the jaw opening to be adjusted so the pliers can grasp components of various sizes.

Diagonal cutting pliers are used to cut wire and to remove cotter pins. See Figure 6-10B. Long-nose pliers are shown in Figure 6-10C. These pliers are often used to recover washers or nuts that have dropped into inaccessible areas. They are also helpful in positioning small parts.

The opening of interlocking joint pliers, or channel locks, can be adjusted to several different positions. This allows the jaws to remain almost parallel regardless of the size of the opening. See Figure 6-10D.

The jaws on locking pliers, Figure 6-10E, can be locked in position on a part. These pliers grip very firmly. Locking pliers can be used to remove rounded-off nuts or bolts. They can also be used as welding clamps when replacing panels.

Snap ring pliers are used to remove and install snap rings. Snap ring pliers are shown in Figure 6-10F. Snap rings are used to secure a component in a hole or on a shaft. Both internal and external snap rings are available. Internal snap rings fit into a groove cut in a hole, or bore. External snap rings fit into a groove cut in a shaft or pin.

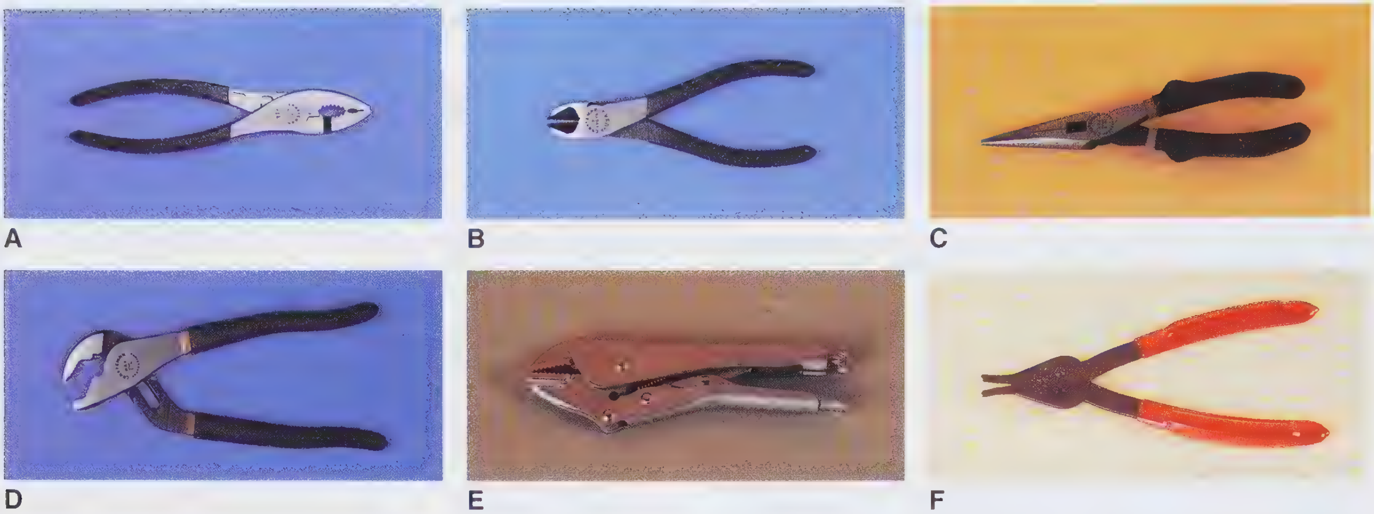


Figure 6-10. *The collision repair technician should have access to several types of pliers. A—Slip-joint pliers. B—Diagonal cutting pliers. C—Long-nose pliers. D—Interlocking joint pliers. E—Locking pliers. F—Snap ring pliers.*

Screwdrivers

The collision repair technician should have a variety of ***screwdrivers*** in several sizes. **Figure 6-11** shows different types of screwdrivers. The most common screwdrivers for collision repair are the standard, Phillips, and Torx screwdrivers. Screwdrivers should be used only to remove fasteners. They should never be used to pry on objects. Screwdriver shafts are made of hardened metal, and they may shatter if used as a prying tool.

Make sure the screwdriver tip is properly seated before turning the screwdriver. Phillips screwdrivers can be easily damaged if they are allowed to slip from the screw. Torx ends can also be damaged. Check Torx tips for damaged points. Replace screwdrivers when their tips become worn.

Some screwdrivers are available with interchangeable drive bits. These screwdrivers may have a ratcheting handle that speeds fastener installation and removal.

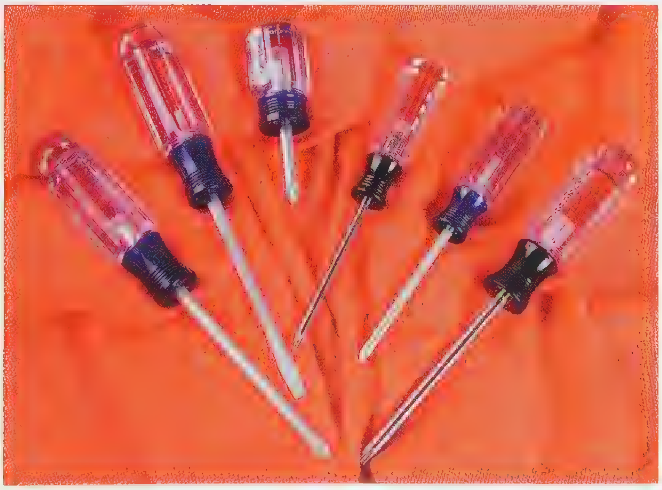


Figure 6-11. *Long and short Phillips, flat, and Torx screwdrivers will be used to remove most screws on a vehicle.*

Pry Bars

Pry bars can be used for prying and aligning. See **Figure 6-12**. These tools are designed to withstand a great deal of force. When prying, make sure the surface the bar rests against is solid. Injury or part damage can occur if the pry bar slips.

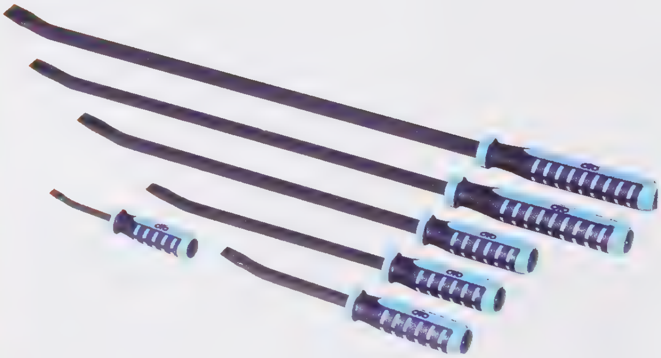


Figure 6-12. *A set of pry bars of different lengths can move or align most vehicle parts or panels.*

Hammers

Hammers can be used for tapping and aligning. See **Figure 6-13**. A ball peen hammer is the most common general-purpose hammer used in the shop. It has a round face and a flat face, and can be used to drive chisels or punches. The ball peen hammer can also be used to shape metal. A dead blow hammer can be used to deliver a solid blow to the work surface without rebounding. This is useful in applications where marring is a problem. The head of a dead blow hammer is loaded with small metal balls called shot. Various dead blow hammers are available, with a one-pound hammer being the most common. A plastic-face hammer can be used without marring the part being hit. Similarly, a rubber mallet will not mar the work surface.

NOTE

Body hammers will be covered in Chapter 7, *Nonstructural Repair Tools, Equipment, and Materials*.

Chisels and Punches

Chisels are used to cut metal and remove rusted or damaged fasteners. **Figure 6-14** shows various chisels. A chisel can also be used to locate spot welds and separate welded panels. The chisel is either held in the hand or

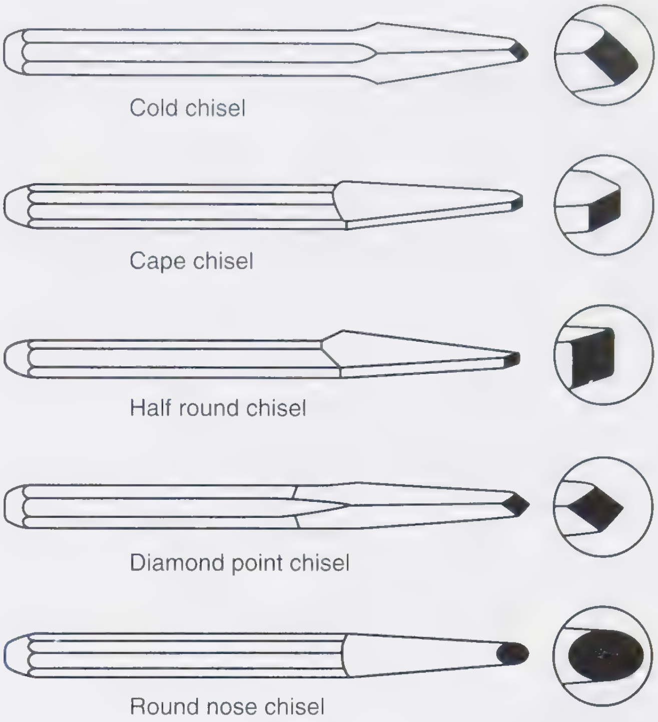


Figure 6-14. *The collision repair technician should have several types of chisels. The cold chisel is the most useful type used in bodywork.*

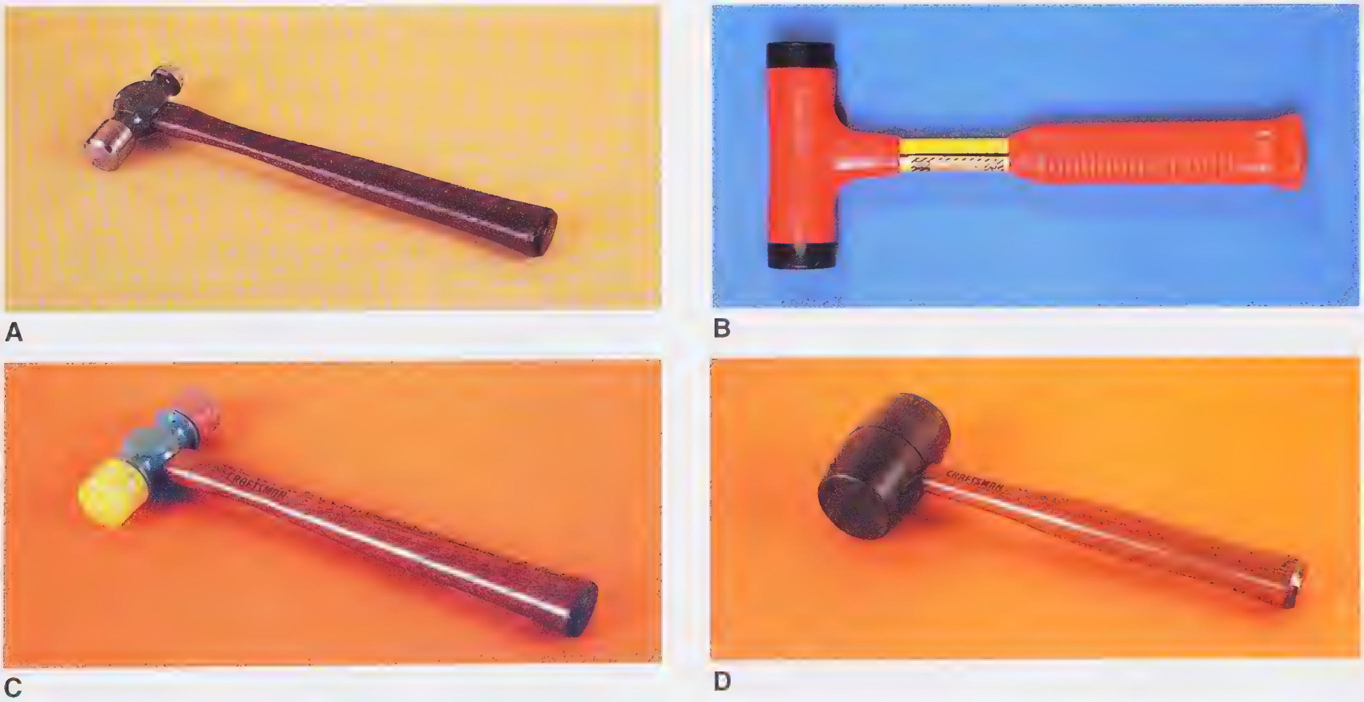


Figure 6-13. *Many of the hammers used in the collision repair shop are shown here. A—Ball peen hammer. B—Dead blow hammer. C—Plastic-faced hammer. D—Rubber mallet.*

secured in a chisel handle, and is struck with a hammer. Using a chisel handle helps prevent the technician's fingers from being hit by the hammer. The cutting face of the chisel should be kept sharp by filing or grinding. If the impact end of the chisel becomes mushroomed, it should be dressed to remove the mushroomed metal.

There are many different types of ***punches*** used in the collision repair shop. The starting punch has a tapered shaft and is used to start driving out straight or tapered pins. After the pin has been driven partly from its hole, the starting punch can no longer be used because of its taper. Therefore, a pin punch is used to complete the job of pushing out the pin. See **Figure 6-15**. The starting punch can also be used to drive out rivets after the heads have been cut off.

An aligning punch, **Figure 6-16**, has a long tapered shaft. It is used to shift parts to bring corresponding holes into alignment. The center punch is ground to a sharp point. It is used to mark the locations of holes that are to be drilled. See **Figure 6-17**. The indentation made by the center punch prevents the drill bit from wandering when starting the hole.

Tap and Die Set

Threads can be damaged during fastener removal or installation. Threads can also become clogged with rust or hardened grease. A ***tap and die set*** is shown in **Figure 6-18**. The tools in this set are used to clean up or reshape the threads on nuts and bolts. They can also be used to cut new threads.

To use a tap and die set to clean or repair threads, the pitch of the dirty or damaged threads must be determined using a gauge. The proper tap or die is then selected and placed in the appropriate holder. Turning a tap through a nut or threaded hole cleans and reshapes

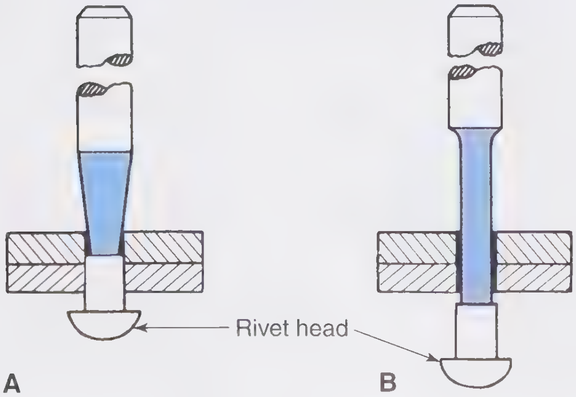


Figure 6-15. *Punches can be used to drive out a pin. A—The starting punch starts to push the pin from its hole. B—The pin punch completes removal.*

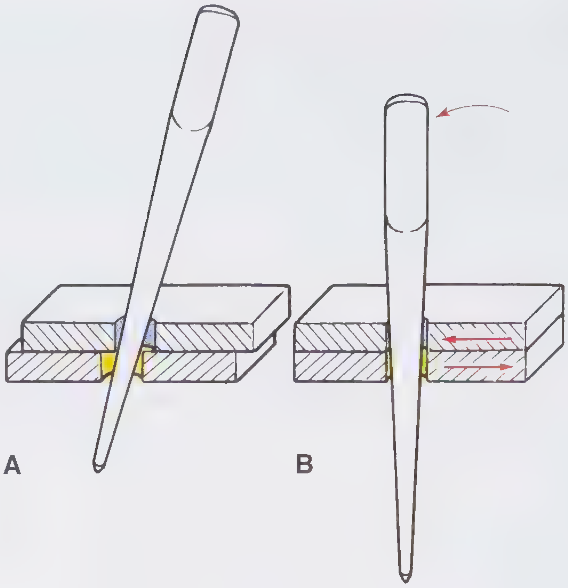


Figure 6-16. *An aligning punch is used to move holes into alignment. A—The holes are misaligned. B—Moving the punch lines up the holes.*

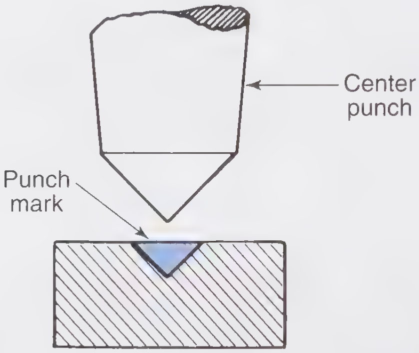


Figure 6-17. *The center punch is used to make an indentation in the metal.*

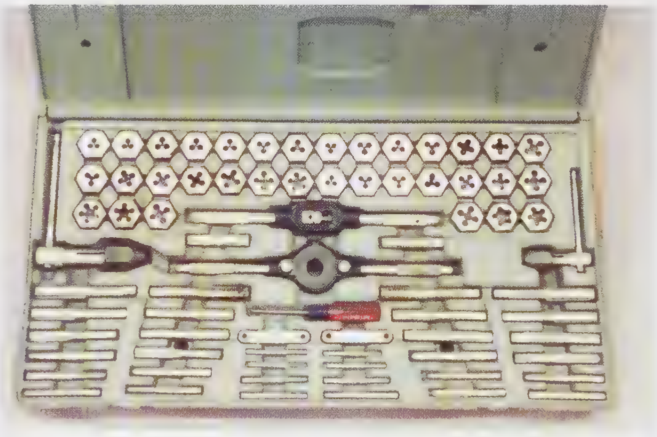


Figure 6-18. *A tap and die set is used to clean or repair threads.*

the threads. The threads of a bolt or threaded rod are cleaned and reshaped by threading the bolt or rod through a die. Cleaning threads is also called chasing.

Hacksaw

A ***hacksaw***, **Figure 6-19**, is used to cut metal. The hacksaw consists of an adjustable metal frame and a detachable cutting blade. Hacksaw blades are available in 8", 10", and 12" lengths. A hacksaw can be used to cut a panel that is less than 5" wide. Anything wider than this will not fit through the saw.

The hacksaw blade should be installed with the teeth pointing away from the handle. In this way, the blade cuts on the forward stroke. Before using a hacksaw, scribe a cut line or lay out the cut line with masking tape. This will help keep the cut straight. Begin the cut with short strokes. Once the cut has been established, long strokes can be made. Keep the blade tight in the saw. A loose saw blade will flex too much and break.

Snips

Snips are useful for making short, quick cuts in metal. A cut that is longer than 6" is very difficult to make using snips. It is best to use a power tool for long cuts. Various types of snips are shown in **Figure 6-20**.

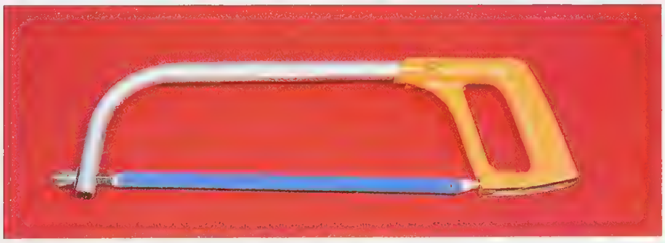


Figure 6-19. *A hacksaw is used to cut metal.*

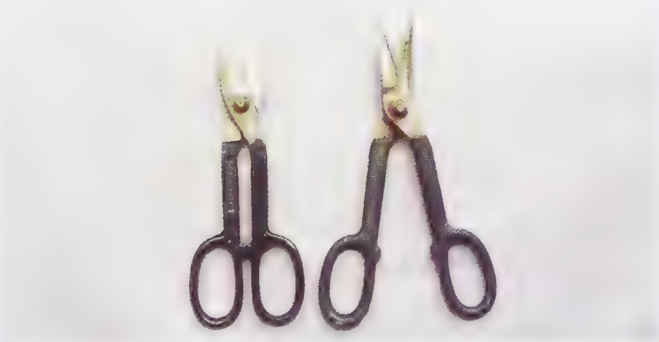


Figure 6-20. *These two types of tin snips make straight cuts.*

Rivet gun

A ***rivet gun***, **Figure 6-21**, is used to install blind rivets, also called Pop® rivets or rivets. ***Blind rivets*** are nonthreaded fasteners used to join metal together. They are permanent fasteners in that they cannot be removed and reused. Blind rivets are available in various sizes, **Figure 6-22**. In collision repair work, metal panels can be held together with 1/8" or 3/16" rivets. Some window glass and door handles are fastened with 1/4" rivets.

To join two pieces of metal with a blind rivet, a hole is drilled through both pieces with a bit that is the recommended size for the rivet. The mandrel end of the rivet is inserted into the rivet gun, and the rivet itself is inserted through the holes in both pieces of metal. As the rivet

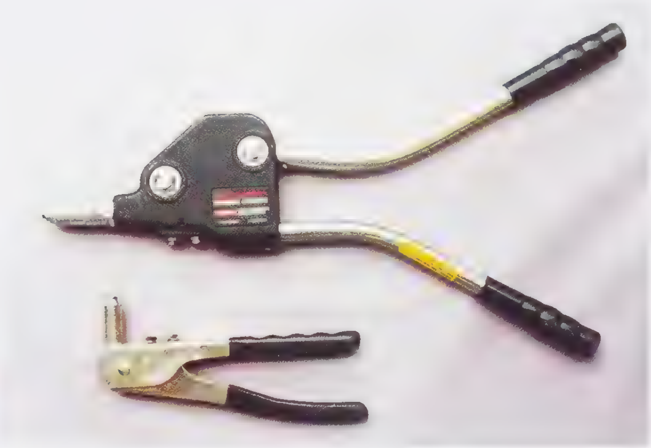


Figure 6-21. *Two different rivet guns are shown here. The long handles on the larger gun provide more leverage, making it easier to install large rivets.*

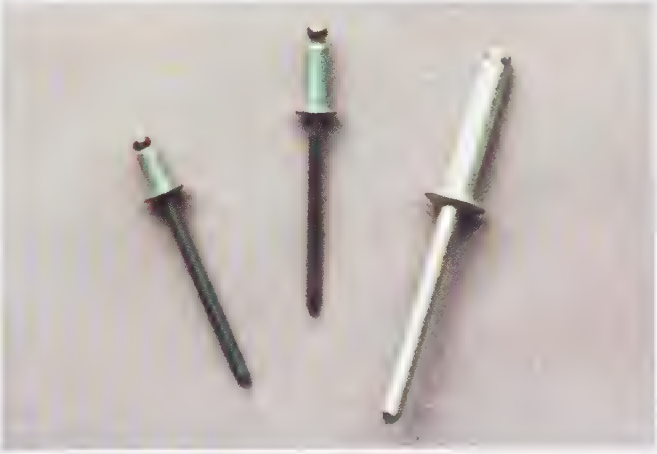


Figure 6-22. *Pop rivets are available in several different sizes.*

gun handle is pumped, the mandrel's head is pulled against the rivet. This causes the rivet to mushroom, pulling the metal pieces together. When the rivet has mushroomed completely and the metal pieces are as close together as possible, additional handle pumping causes the mandrel to break off. This leaves the rivet holding the metal pieces together. Make sure the mandrel is released from the rivet gun before inserting another rivet in the gun.

Scrapers

Scrapers are shown in **Figure 6-23**. A scraper can be used to remove glued-on moldings and to separate bonded panels. The blade of the scraper should be flat, with no nicks on the edge. A ragged edge can be squared up by filing or grinding. The scraper should have a blade that extends under the entire length of its handle. This allows a hammer to be used to tap on the end of the handle. A scraper that has a non-continuous blade may simply bend in half when a hammer is used on the handle end.

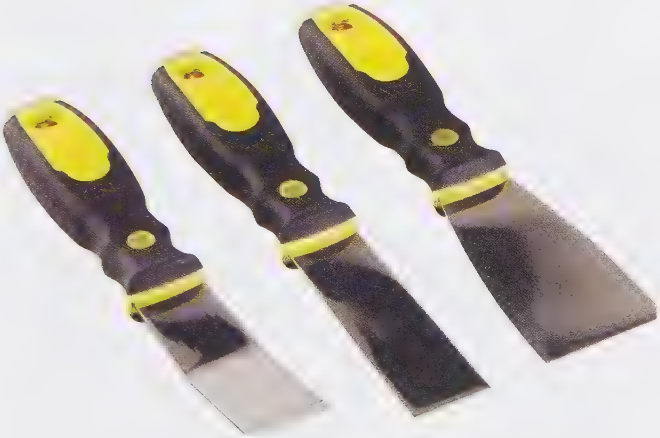


Figure 6-23. *Scrapers can be used to remove undercoating and glued-on molding from damaged panels.*

Utility Knives

A ***utility knife***, **Figure 6-24**, is very useful for opening part boxes and cutting adhesives. The utility knife has a handle that holds a retractable razor blade that is replaceable. Be careful when using a utility knife. The razor blade is extremely sharp. Change the blade when it becomes dull or nicked.

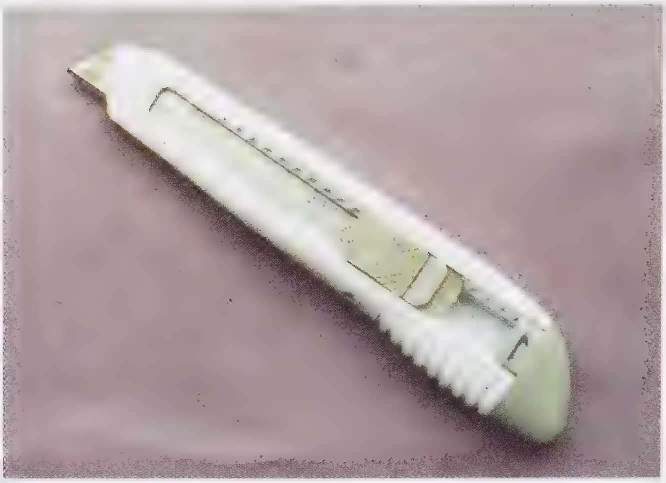


Figure 6-24. *This utility knife has a blade that extends from the handle. When the blade end becomes dull, it can be snapped off to expose a new cutting edge.*

Upholstery Removal Tools

Upholstery removal tools are designed to remove door trim panels, fender liners, and interior trim. See **Figure 6-25**. To use the trim and panel tools shown in Figures 6-25A and B, the tool is slid under the head of the fastener. The shaft of the plastic fastener fits into the notch in the tool. The offset shaft of the tool is pushed down to provide leverage to pull the clip out.

A tool used to remove the window regulator crank handle clip is shown in Figure 6-25C. This tool slides between the window regulator crank handle and the door trim. The clip that holds the window handle on is pushed out by the tool.

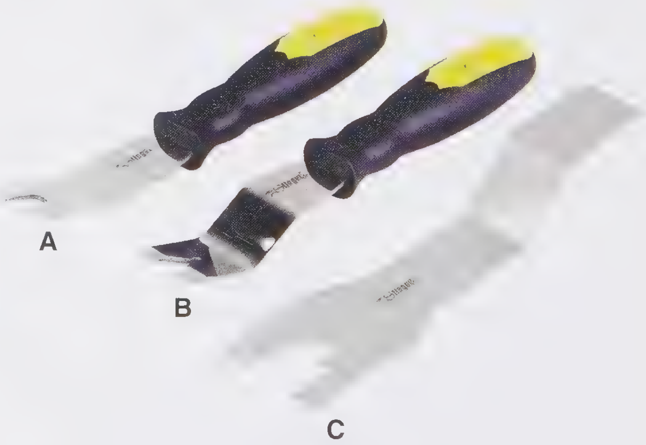


Figure 6-25. *A—U-blade trim panel removal tool. B—V-blade trim panel removal tool. C—Door and window handle removal tool.*

Power Tools

Power tools either speed up operations or allow a technician to make repairs that would be impossible with hand tools. Power tools can be either pneumatic or electric. Pneumatic, or air-driven, tools are the most common type of power tool in automobile repair. However, certain types of electric tools are also used in the collision repair shop.

All power tools require maintenance. Electric tools should be blown out with compressed air to remove dust from their electric motors. Cords should be checked periodically for cuts or fraying. Damaged cords should be replaced. Air tools should be supplied with clean, dry air. Compressed air that contains moisture or contaminants may damage an air tool. Air tools should be lubricated with two drops of air tool oil before each use.

WARNING

Always wear safety glasses when using power tools.

Impact Wrench

An ***impact wrench*** can exert up to 200 ft lb of torque on a fastener. A 1/2"-drive impact wrench is shown in **Figure 6-26**. This air tool is useful when working on suspension, steering, or drive train components. When trying to break loose a fastener with an impact wrench, simply pull the trigger and let the impact wrench do the work. It may take a few seconds for the impact force to loosen the fastener.

WARNING

Use only impact sockets with an impact wrench. These sockets are easily identified by their flat-black finish. Standard chrome sockets cannot withstand the forces created by the impact wrench and may shatter violently, causing serious injury. Note that impact sockets are shown in Figure 6-26.

Air Ratchet

An ***air ratchet*** can be used to remove nuts and bolts. In a confined area, an air ratchet is more useful than a manual ratchet because an air ratchet handle does not have to move to remove the fastener. The air ratchet is small and compact, allowing it to reach into narrow spots. **Figure 6-27** shows a 1/4"-drive air ratchet. Air ratchet types can vary in the amount of power they produce. In general, a 1/4"-drive air ratchet is less powerful than a 3/8"-drive ratchet. A 1/4"-drive air ratchet is adequate for fender, deck lid, and hood fasteners. For door and bumper removal, a 3/8"-drive air ratchet should be used. If a nut or bolt will not turn when trying to remove it, manually turn the ratchet to break the fastener loose. Then pull the trigger to remove the fastener.

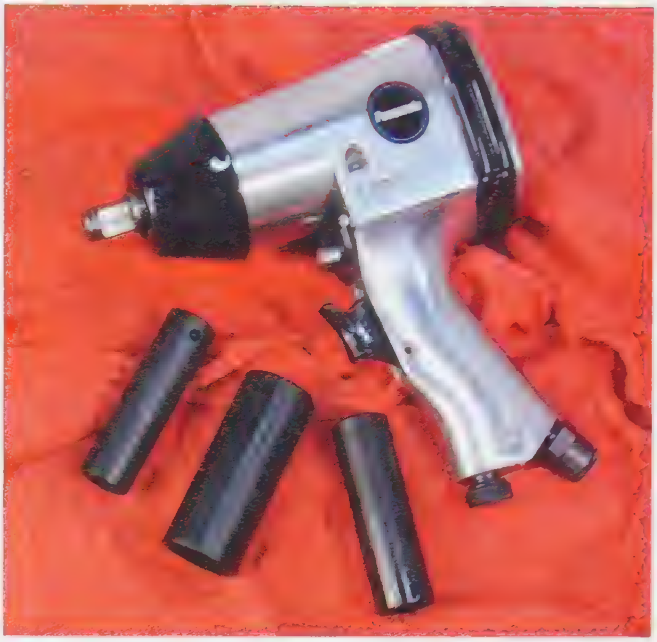


Figure 6-26. *This particular impact wrench has a maximum torque rating of 200 ft lb. Notice the impact sockets. This type of socket must be used with an impact wrench.*

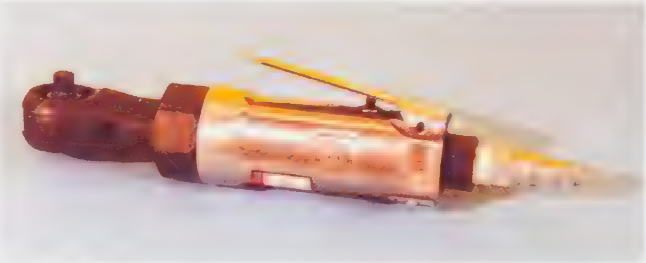


Figure 6-27. *This small air ratchet can fit into confined spaces.*

Drills and Drill Bits

Drills and ***drill bits*** are used to make holes in replacement panels and other parts. The drill is either pneumatic (air-powered) or electric. Electric drills can be either corded or cordless (battery powered). Three types of drills are shown in **Figure 6-28**.

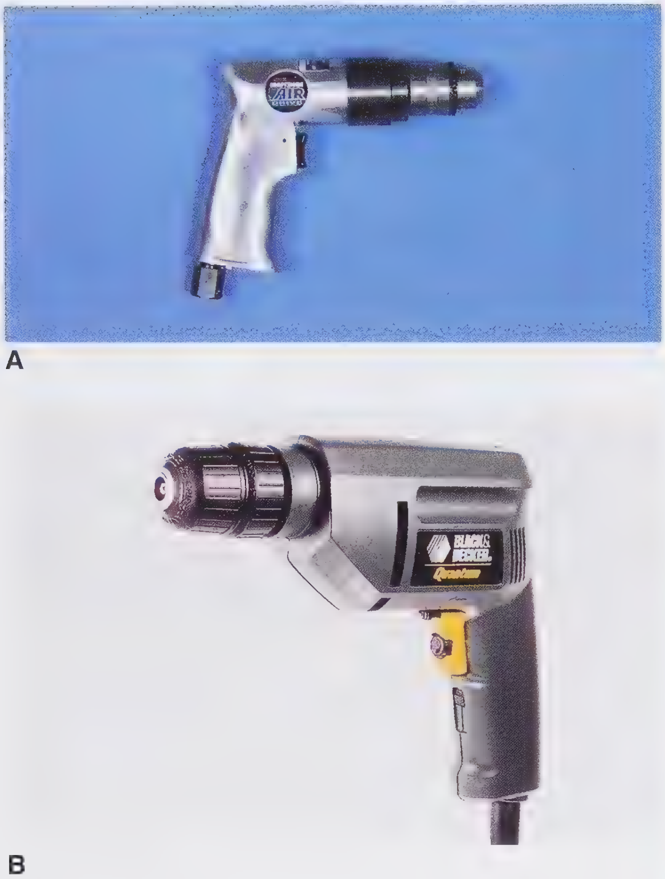


Figure 6-28. *Drills can be powered electrically or pneumatically. A—Pneumatic drill. B—Corded electric drill.*

Drills may be variable speed and/or reversible. Variable speed means that the farther the trigger is pulled, the faster the drill turns. Reversible means that the drill can turn both clockwise and counterclockwise.

A drill bit set is shown in **Figure 6-29**. The set contains drill bits of various diameters. The most common drill bits used in collision repair are 1/8" bits. These bits can be used to make pilot holes, as well as holes for sheet metal screws. A ***pilot hole*** is a small hole drilled in a panel to help in the alignment of a larger drill bit.

Shop Equipment

Shop equipment is generally supplied by the collision repair shop. The technicians share the use of this equipment. Although technicians can buy the equipment detailed in the following section, it is usually not required since the shop will have them available. In high-production shops, some technicians may elect to buy some shop equipment to avoid having to share it.

Figure 6-29. *The collision repair technician should have access to a variety of drill bits.*

Compressed Air System

The ***compressed air system*** supplies the collision repair shop with a source of clean, dry compressed air. This air is used for a variety of tasks around the shop, including powering pneumatic tools and spraying paint. The compressed air system consists of an air compressor, air dryer, air piping, air regulators, and air hoses.

NOTE

Compressed air systems are covered in detail in Chapter 24, *Refinishing Tools and Equipment*.

Floor Jack

A ***floor jack***, **Figure 6-30**, can be used to raise a vehicle. It can also be used to move vehicles with damage that prevents the front or rear wheels from turning. To accomplish this, the jack is used to raise the entire front or rear of the damaged vehicle. The

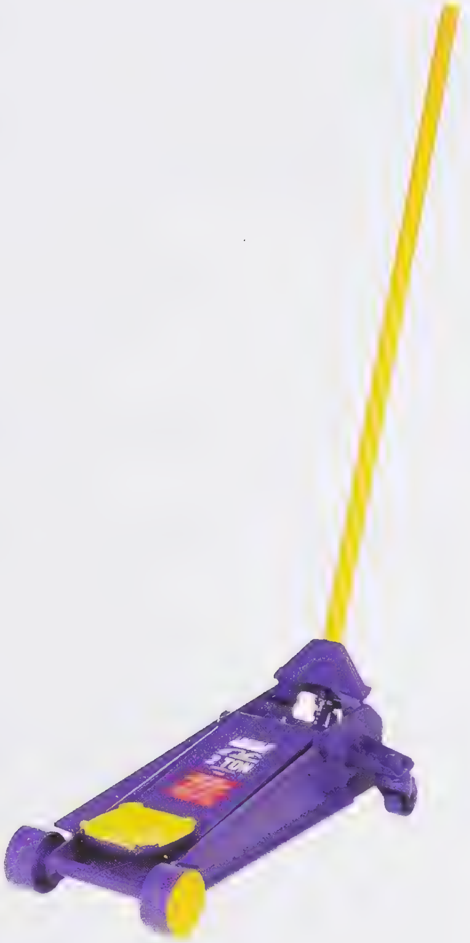


Figure 6-30. *A floor jack is used to raise a vehicle. A vehicle raised with a floor jack should be placed on jack stands before working under it.*

jack is then pulled or pushed to move the vehicle to the desired location.

The jack must be placed under a strong section of the vehicle. Select a cross member, unirail, or frame rail as a lift point. Never try to raise the vehicle by the drive train, as this may damage a drive train component or allow the vehicle to slip from the jack and fall to the ground. Most service manuals contain information on recommended lift points.

After positioning the jack under an appropriate lift point, pump the handle until the saddle contacts the vehicle. Check the saddle position to make sure it will not slip as the vehicle is raised. If necessary, lower the jack and reposition the saddle. With the saddle in the correct position, slowly pump the handle to raise the vehicle to the desired height.

Floor jacks need hydraulic oil in order to operate. The oil level should be checked periodically and when the jack is not operating properly.

WARNING

Never work under a vehicle supported by only a floor jack. The jack can fail suddenly, allowing the vehicle to drop to the ground with lethal force.

Jack Stands

Jack stands are used to support a vehicle after it has been raised with a jack. Jack stands are adjustable, allowing the vehicle to be secured at the proper height. See **Figure 6-31**. Raise the vehicle to the desired height and position jack stands in recommended locations under the vehicle. Then, lower the vehicle onto the jack stands.

Lifts

There are several types of ***lifts*** used to raise vehicles in the repair shop. A below-ground lift is shown in **Figure 6-32**. This type of lift uses a large hydraulic cylinder that is recessed in the shop floor. The vehicle is driven over the lift and the lift's arms are positioned under the vehicle's lift points. The lift is then used to raise the vehicle. The main drawback to a below-ground lift is that the cylinder obstructs the underside of the vehicle.

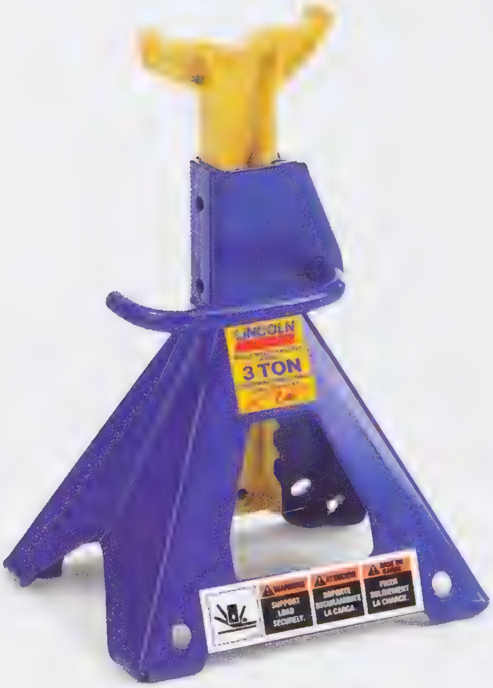


Figure 6-31. *Jack stands are used to support a vehicle raised by a floor jack.*

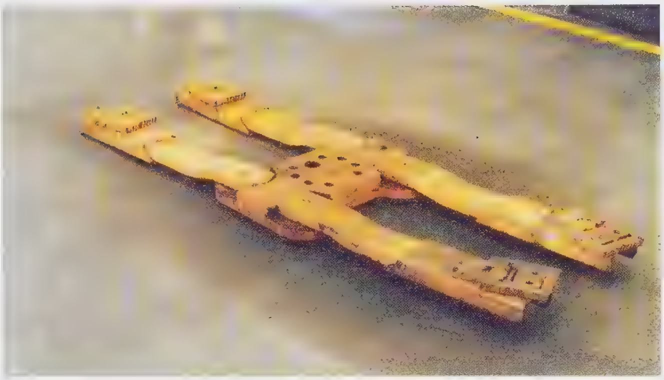


Figure 6-32. *A vehicle is driven over a below-ground lift. The lift's arms are then positioned under the vehicle's lift points.*

There are two types of above-ground lifts—two-post lifts and four-post lifts. A two-post lift raises the vehicle on four arms. See **Figure 6-33**. These arms are positioned under the vehicle's lift points. The steps to raise a vehicle on a two-post lift are as follows:

1. Drive the vehicle to the lift.
2. Position the vehicle so that the arm saddles can reach the lifting points on the vehicle.
3. Arm saddle extensions can be raised to contact the frame and equal out the height.
4. Raise the vehicle slightly off the ground.
5. Push on the vehicle to see if it wobbles. If so, lower the vehicle, reposition the arms, and repeat step 4, making sure the vehicle does not wobble.
6. Look under the vehicle to make sure the saddles are correctly positioned.
7. Raise the vehicle to the desired height.
8. Lower the vehicle until the lift clicks into a lock. Do not go under the vehicle until the lift is locked into place.
9. To lower the vehicle, some lifts require that the vehicle be raised slightly so the locks can be released. After releasing the locks, slowly lower the vehicle to the ground.

The four-post lift is equipped with ramps that move up and down between the posts. The vehicle is simply driven onto the ramps and the ramps raise the vehicle by the wheels. See **Figure 6-34**. The four-post lift is the easiest type of lift to use, as the vehicle is simply driven onto the ramps. However, unless an auxiliary lift is available, the wheels cannot be removed from a vehicle raised by a four-post lift.

Power train lifts are used when removing or installing an engine and transaxle. Most are powered hydraulically. This type of lift can also be used when removing or installing gas tanks and drive axle assemblies.

As the name implies, a transmission jack is designed specifically to aid the removal and installation of transmissions and transaxles. An engine crane, also known as a cherry picker or a hoist, can be used to remove an engine from above the engine compartment.

WORKING SMART

Unibody vehicles can be raised at the pinch welds on the rocker panels, or by the front unirails under the cowl and at the rear spring mount. Full-frame vehicles can be raised by the frame at the cowl and at the rear spring mount.

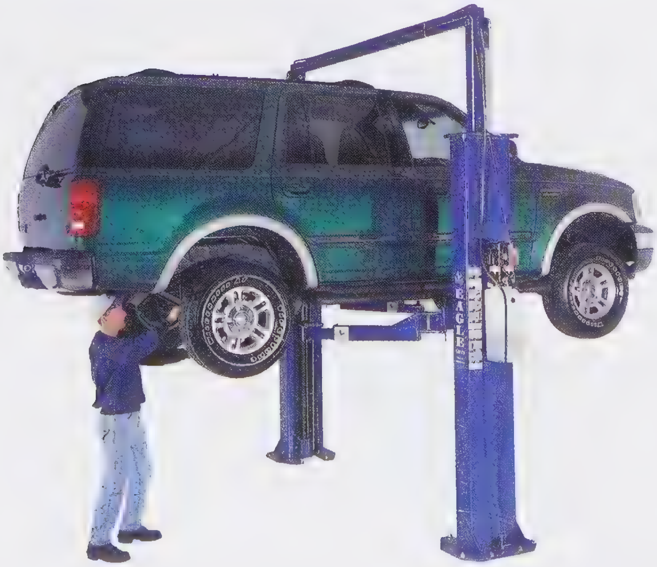


Figure 6-33. *A two-post lift raises the vehicle on four arms.*

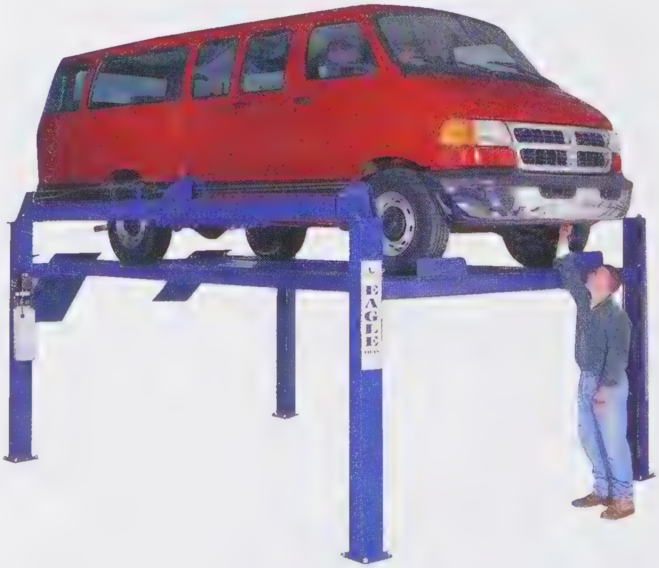


Figure 6-34. *A four-post lift raises the vehicle on two drive-on platforms.*

Creepers and Shop Seats

A technician can work under a vehicle while lying on a ***creeper***. The creeper has wheels, allowing it to roll easily under the vehicle. **Figure 6-35** shows one style of creeper. A shop seat is shown in **Figure 6-36**. The shop seat allows the technician to sit when repairing the side of a vehicle.

Service Cart

A ***service cart***, **Figure 6-37**, can be used to transport tools from the toolbox to the vehicle. At the vehicle, the tools can be kept within reach for easy access. With the wheels locked and a piece of plywood placed across the handles, a service cart can function as a light-duty workbench.

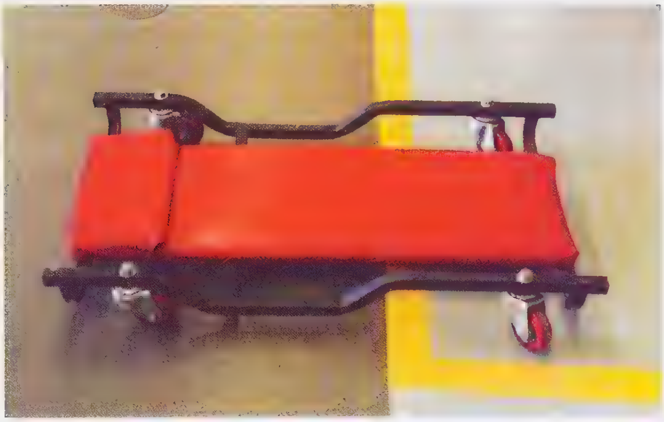


Figure 6-35. *A creeper is used when working under a vehicle.*

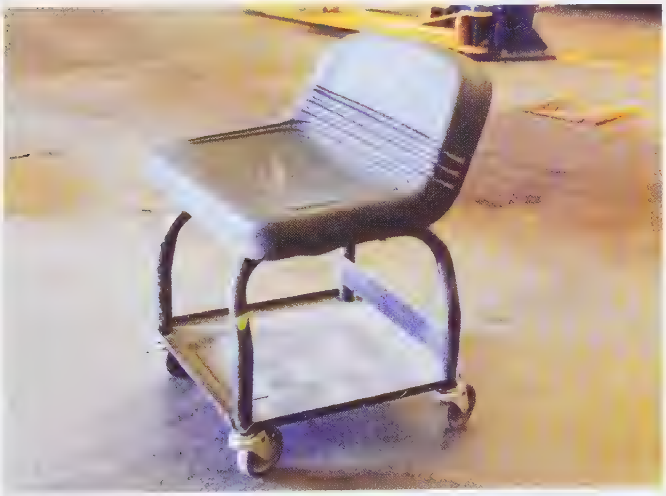


Figure 6-36. *A shop seat helps when working on the lower parts of a vehicle.*

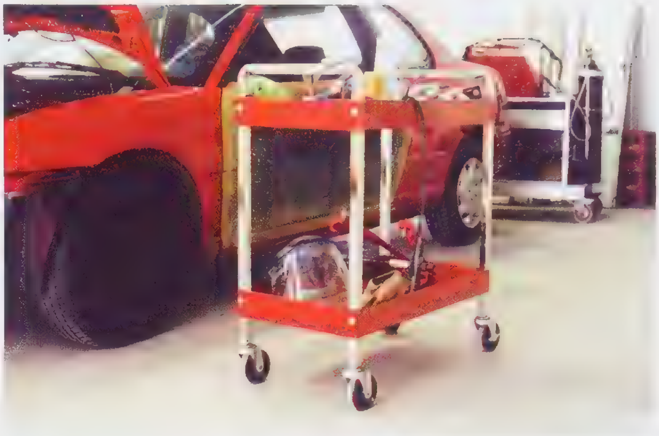


Figure 6-37. *A service cart can be used to transport tools and parts.*

Welding Equipment

Most collision shop welds are made with a ***MIG welder***. MIG welders can be used to make several types of welds on different joints. They can be set up to weld steel or aluminum.

Both 110- and 220-volt MIG welders are commonly used in collision repair shops. A 110-volt MIG welder is best suited for joining structural and non-structural sheet metal panels. Typical applications include radiator support replacement and quarter panel replacement. A 220-volt MIG welder has enough power to weld heavier steel, such as that used in a full frame. Many 220-volt welders can be adjusted to weld sheet metal. See **Figure 6-38**.

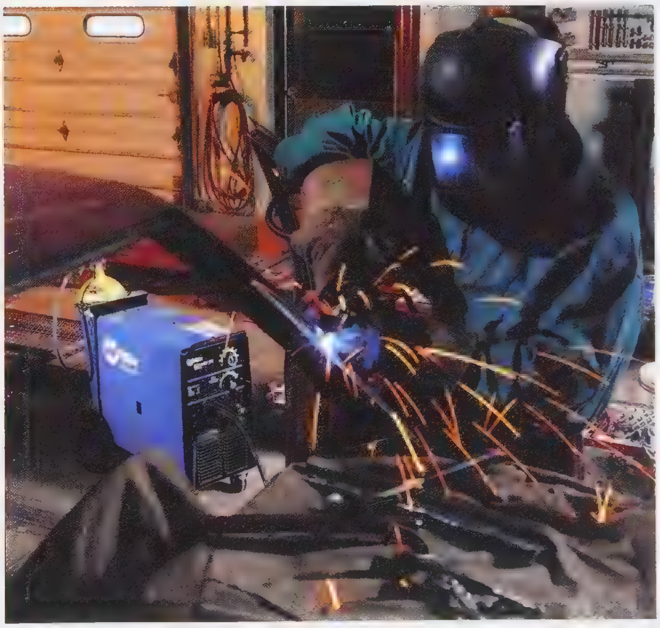


Figure 6-38. *This technician is using a MIG welder. (Lincoln)*

Collision repair shops will also have oxyacetylene equipment. This equipment is not used for welding. Instead, the oxyacetylene flame is used to heat metal when shrinking a stretched panel or repairing a full frame.

Many collision repair shops have a squeeze-type resistance spot welder. This welder duplicates factory spot welds, even on structural panels. Some shops use a TIG welder for steel or aluminum welding.

NOTE

For more information on welding, refer back to Chapter 5, *Welding and Cutting*.

Service Information

Service information includes instructions for repairing or replacing damaged components, as well as information on refinishing. Service information is available from vehicle manufacturers, information providers, collision repair equipment manufacturers, and collision repair material manufacturers. The information may be available in printed service manuals, on CDs, or on the Internet. The service manuals and CDs must be purchased. Some of the information on the Internet is available by paid subscription and some is free.

Vehicle manufacturers provide extensive service information for troubleshooting and repairing both mechanical and electrical systems. The procedures for replacing mechanical components, such as suspension, drive train, steering, or restraint system components, are covered thoroughly. Torque values for fasteners are given. Troubleshooting procedures are often detailed. Service information often contains troubleshooting charts. These charts give the step-by-step checks to make to isolate the source of a problem.

The amount of service information available for body repair varies from one vehicle manufacturer to another. Some manufacturers supply considerable body service information, while others supply very little, if any. Vehicle manufacturers may list vehicle dimensions. Dimensions are measurements of an undamaged vehicle. Comparing these dimensions to the measurements taken from a damaged vehicle helps the technician determine the extent of the damage.

The repair of a damaged vehicle may require that only a portion of a damaged welded-on panel, such as quarter panel or lower frame rail, be replaced. This is called splicing. Some vehicle manufacturers list recommended splice locations and welds for various panels. The location of high-strength steel parts may be given by the manufacturer. The identification and repair of plastic parts may also be included in vehicle manufacturer's service information.

Information providers, such as Motor or Mitchell, are also sources of service information. The mechanical replacement procedures from these providers may be less extensive than the vehicle manufacturer's procedures. Body repair information from information providers includes dimensions and replacement procedures for bolt-on and welded-on parts. Information providers may also offer collision estimating guides. These guides list part names, part prices, and labor times for various replacement and refinish operations to serve as a reference when writing an estimate of the cost to repair a damaged vehicle.

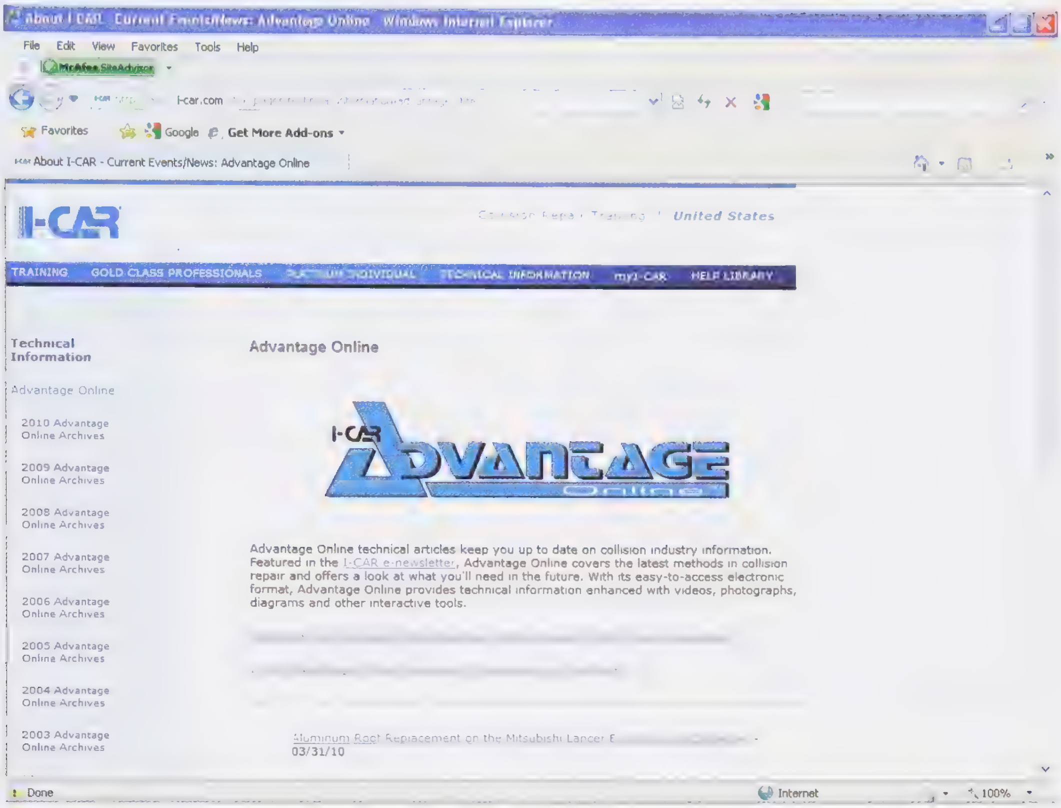
I-CAR is a nonprofit organization that provides information specifically for the collision repair industry. I-CAR provides an extensive amount of material on its website. Features on the I-CAR website include:

- I-CAR Advantage Online—Articles about repairing collision damage on specific parts or specific vehicles. See **Figure 6-39**.
- Top Tech Inquires—Questions and answers about plastic identification, high-strength steel identification, air bag replacement, and high-strength steel heating requirements.
- Air bag replacement procedures—Listed by vehicle.
- Uniform procedures of collision repair—List of steps to follow in the replacement or repair of vehicle components commonly damaged during a collision.
- Vehicle manufacturer's technical information—Access to vehicle manufacturers' websites.
- Vehicle sectioning technical inquires—Questions and answers about splice locations on various vehicles.

I-CAR also provides both classroom and online training on a wide range of collision repair topics.

Another service information provider is Tech-Cor. Tech-Cor researches collision repair procedures and publishes its findings in the form of automotive research bulletins on their website. Topics of these bulletins include service precautions for hybrid vehicles, adhesive bonding of nonstructural panels, structural sectioning on specific vehicles, and tricoat refinishing. Tech-Cor will also answer your technical questions via e-mail. See **Figure 6-40**.

Repair equipment manufacturers publish service information to help technicians use their products. For example, a frame repair equipment manufacturer may provide dimension guides or measurements for vehicles, as well as set-up instructions for tie-down equipment for full-frame vehicles. The information may be available on the Internet, in a printed manual, or on a CD included with the purchase of the equipment. Spray gun manufacturers supply information on how to adjust their spray guns for specific types of paint.

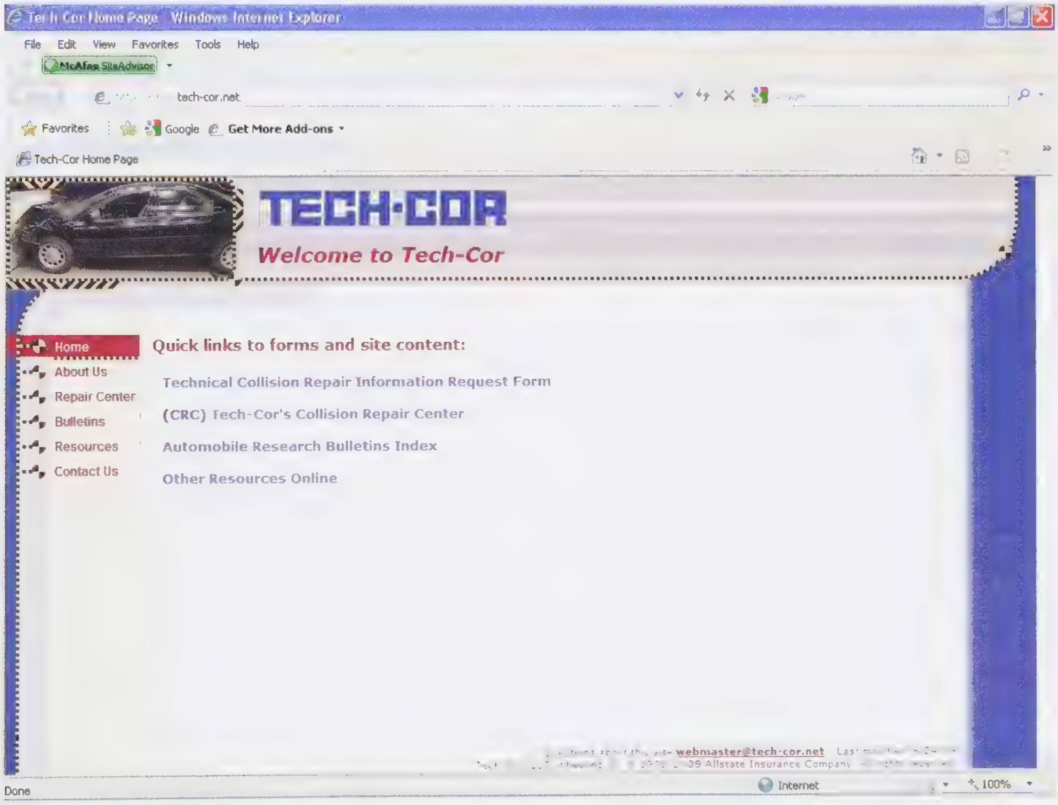

About I-CAR - Current Events/News: Advantage Online - Windows Internet Explorer
File Edit View Favorites Tools Help
McAfee SiteAdvisor
i-car.com
Favorites
Google
Get More Add-ons
About I-CAR - Current Events/News: Advantage Online
I-CAR
United States
TRAINING
GOLD CLASS PROFESSIONALS
PLATINUM INDIVIDUAL
TECHNICAL INFORMATION
myI-CAR
HELP LIBRARY
Technical Information
Advantage Online
2010 Advantage Online Archives
2009 Advantage Online Archives
2008 Advantage Online Archives
2007 Advantage Online Archives
2006 Advantage Online Archives
2005 Advantage Online Archives
2004 Advantage Online Archives
2003 Advantage Online Archives
I-CAR Advantage Online
Done
Internet
100%

Advantage Online

Advantage Online technical articles keep you up to date on collision industry information. Featured in the I-CAR e-newsletter, Advantage Online covers the latest methods in collision repair and offers a look at what you'll need in the future. With its easy-to-access electronic format, Advantage Online provides technical information enhanced with videos, photographs, diagrams and other interactive tools.

Aluminum Roof Replacement on the Mitsubishi Lancer E
03/31/10

Figure 6-39. *The I-CAR website is a valuable source of information on a variety of collision repair topics.*


Tech-Cor Home Page - Windows Internet Explorer
File Edit View Favorites Tools Help
McAfee SiteAdvisor
tech-cor.net
Favorites
Google
Get More Add-ons
Tech-Cor Home Page
TECH-COR
Welcome to Tech-Cor
Home
About Us
Repair Center
Bulletins
Resources
Contact Us
webmaster@tech-cor.net
Allstate Insurance Company
Done
Internet
100%

Quick links to forms and site content:

Technical Collision Repair Information Request Form

(CRC) Tech-Cor's Collision Repair Center

Automobile Research Bulletins Index

Other Resources Online

Figure 6-40. *Technicians can get answers to technical questions by accessing the Tech-Cor website.*

Collision repair and refinishing material manufacturers are the final source of service information. Paint manufacturers publish instructions for using specific products, including information on the mixing ratios, drying times, and the number of coats required for each type of paint. They also publish instructions for troubleshooting specific refinishing problems. This information may be available in printed manuals or on the manufacturers' websites.

All paint manufacturers distribute color chip books or CDs. The color chip book lists the vehicle paint code and the paint part number, and includes a chip painted with the color. A color chip CD has the vehicle paint code and paint part number, but only shows an approximation of the color. Printed tinting guides that aid in color matching may also be available. These guides describe how the addition of specific tints changes a color.

Manufacturers of repair materials also publish service information, often on their websites. For example, abrasive manufacturers list recommended sandpaper grits for various tasks, such as sanding a scratch (featheredging) and sanding body filler level (block sanding). Manufacturers of buffing products offer color sanding and buffing instructions to remedy a variety of conditions, including acid rain damage, excessive orange peel, and clearcoat scratches.

Material manufacturers also publish material safety data sheets (MSDS) for all their products. Material safety data sheets list storage, handling, and application information, as well as fire and toxicity precautions.

Summary

- Tools are generally available in three grades: professional, hobbyist, and homeowner.
- A toolbox is used to store and organize tools. It also protects tools when they are not being used.
- Wrenches are used to tighten or loosen nuts and bolts.
- Pliers are designed to grip or cut various objects. They should never be used in place of a wrench.
- The collision repair technician should have a variety of screwdrivers in several sizes.
- Chisels are used to cut metal and remove rusted or damaged fasteners.
- A tap and die set is used to clean up or repair threads on nuts and bolts. It can also be used to cut new threads.
- A scraper can be used to remove glued-on moldings and to separate bonded panels.
- A utility knife is very useful for opening part boxes and cutting adhesives.
- Upholstery removal tools are designed to remove door trim panels, fender liners, and interior trim.
- Power tools either speed up operations or allow a technician to make repairs that would be impossible with hand tools.
- An impact wrench can exert up to 200 ft lb of torque on a fastener.
- Drills and drill bits are used to make holes in replacement panels and other parts.
- A floor jack is commonly used to raise a vehicle. It can also be used to move vehicles with damage that prevents the front or rear wheels from turning.
- Jack stands are used to support a vehicle after it has been raised with a jack.
- A service cart can be used to transport tools from the toolbox to the vehicle.
- Most collision shop welds are made with a MIG welder or a squeeze-type resistance spot welder.
- Oxyacetylene equipment is used to heat metal when shrinking sheet metal or repairing a full frame.
- Service information is available in printed service manuals, on CDs, or on the Internet.

Review Questions

Please do not write in this textbook. Place your answers on a separate sheet of paper.

1. A chest-and-cabinet toolbox can be rolled to the work site. True or False?
2. A combination wrench has a(n) ______end and a(n) ______end.
3. A long ratchet handle can apply more ______ to a fastener than a short ratchet handle.
4. A(n) ______ is used with a ratchet to reach a fastener located in an obstructed area.
5. Pliers should be used to remove small nuts. True or False?
6. A screwdriver is an acceptable substitute for a pry bar for small jobs. True or False?
7. What type of hammer is loaded with shot?
8. A center punch is used to make an indentation before drilling a hole. True or False?
9. Cleaning threads on a bolt is called ______.
10. What type of tool is recommended for removing glued-on molding and separating bonded panels?
11. Why must special impact sockets be used with an impact wrench?
12. A vehicle should never be raised by a drive train component. True or False?
13. On a(n) ______ lift, a vehicle is driven onto ramps and raised by its wheels.
14. Before completely raising a vehicle on a two-post lift, the vehicle should be raised slightly and checked to see if it ______.
15. All vehicle manufacturers provide extensive collision repair information. True or False?

ASE-Type Questions

1. Technician A says that a combination wrench can be used to remove nuts and bolts. Technician B says that a 12-point wrench is less likely to slip than a 6-point wrench. Who is right?
   (A) A only.
   (B) B only.
   (C) Both A and B.
   (D) Neither A nor B.
2. Which of the following is the least likely to cause fitting damage?
   (A) Open-end wrench.
   (B) Slip-joint pliers.
   (C) Channel locks.
   (D) Line wrench.
3. Technician A always uses a deep socket to remove fasteners. Technician B only uses a deep socket when turning a nut on a protruding bolt. Who is right?
   (A) A only.
   (B) B only.
   (C) Both A and B.
   (D) Neither A nor B.
4. Which of the following Torx sockets is the biggest?
   (A) T-15.
   (B) T-25.
   (C) T-30.
   (D) T-50.
5. A large, tight fastener must be removed. Technician A recommends using a breaker bar. Technician B recommends using a speed handle. Who is right?
   (A) A only.
   (B) B only.
   (C) Both A and B.
   (D) Neither A nor B.
6. Which of the following pliers would you use to remove a cotter pin?
   (A) Combination slip joint pliers.
   (B) Diagonal cutting pliers.
   (C) Interlocking joint pliers.
   (D) Locking pliers.
7. Technician A says that screwdrivers must always be properly seated before trying to turn a fastener. Technician B says that screwdrivers should not be used to pry. Who is right?
   (A) A only.
   (B) B only.
   (C) Both A and B.
   (D) Neither A nor B.
8. Which of the following hammers is most useful for a collision repair technician?
   (A) Ball peen.
   (B) Dead blow.
   (C) Plastic face.
   (D) Rubber mallet.
9. Technician A separates welded sheet metal panels with a pin punch. Technician B uses a chisel to separate welded sheet metal panels. Who is right?
   (A) A only.
   (B) B only.
   (C) Both A and B.
   (D) Neither A nor B.
10. Technician A installs a hacksaw blade with the teeth pointing away from the handle. Technician B installs a hacksaw blade loosely so it can flex during use. Who is right?
    (A) A only.
    (B) B only.
    (C) Both A and B.
    (D) Neither A nor B.
11. Which of the following is commonly used to open parts boxes?
    (A) Hacksaw.
    (B) Scraper.
    (C) Utility knife.
    (D) Upholstery tool.
12. Fender bolts must be removed. Technician A says to use a 1/2" impact wrench. Technician B says to use a 1/4" air ratchet. Who is right?
    (A) A only.
    (B) B only.
    (C) Both A and B.
    (D) Neither A nor B.
13. Technician A says a floor jack can be used to move a vehicle. Technician B says to check the level of hydraulic oil in a jack that does not operate properly. Who is right?
    (A) A only.
    (B) B only.
    (C) Both A and B.
    (D) Neither A nor B.
14. A vehicle is being raised on a two-post lift. Technician A says to raise the vehicle slightly and push on it to see if it wobbles. Technician B says the arms must be repositioned if the vehicle wobbles. Who is right?
    (A) A only.
    (B) B only.
    (C) Both A and B.
    (D) Neither A nor B.
15. A structural panel needs to be sectioned. Technician A says to check the I-CAR website for information. Technician B says to check the Tech-Cor website. Who is right?
    (A) A only.
    (B) B only.
    (C) Both A and B.
    (D) Neither A nor B.

Section 2

Nonstructural Repairs

Chapter 7. Nonstructural Tools, Equipment, and Materials
Chapter 8. Nonstructural Panel Repair
Chapter 9. Bolted Nonstructural Panel Replacement
Chapter 10. Welded and Bonded Nonstructural Panel Replacement
Chapter 11. Plastic Repair
Chapter 12. Glass

Chapter 7

Nonstructural Repair Tools, Equipment, and Materials

Objectives

After studying this chapter, you will be able to:

- Describe the hand tools used in nonstructural panel repair.
- Identify the various power tools used when repairing or replacing nonstructural panels.
- Explain why filler is used and describe the different types of filler available.
- Describe the characteristics of various types of sandpaper.
- Describe the use of adhesives in nonstructural repair.

Technical Terms

adhesives
air chisel
air file
air punch/flanger
air saw
alignment bar
body chisel
body fillers
body hammers
bull's-eye pick
catalyst
come-along
cut-off tool
dollies
door skin replacement tool
draw pin welder
electric shears
floor pots
friction jack
grinder
hand punch
hydraulic power set
long boards
metal files
mixing board
orbital sander
panel flanger
picks
power post
pry picks
rod welder
sanding blocks
sanding stick
sandpaper
shrinking
slide hammer
spoon
spot weld cutters
spreader
stretching
surform tool
UV light
weld-on plate

Introduction

Repairing a damaged nonstructural panel involves restoring the panel to the proper contour by pulling or pushing, filling the low areas, and sanding. Usually damaged panels are pulled or pushed with power tools to remove buckles, high areas, and low areas. Filling and sanding may be done with hand tools. This chapter details the hand and power tools used in nonstructural panel repair, as well as the materials required to complete these repairs.

NOTE

This chapter covers the tools commonly used for nonstructural panel repair. Specialty tools and equipment, such as refinishing equipment, will be covered in detail in the appropriate chapters of this textbook.

Body Repair Hand Tools

Body repair hand tools are used to reshape damaged sheet metal, apply body filler, and sand cured filler. Hammers, dollies, long boards, and filler tools are the most commonly used body repair hand tools.

Body Hammers

Body hammers are used to move damaged sheet metal back to its original contour. These hammers have two working surfaces. For simplicity, only one working surface will be specified at a time. For example, the body hammer shown in **Figure 7-1** has a flat face and a pointed end. When the flat face is used, the hammer is called a dinging hammer. A dinging hammer is used to lower a high area or raise a low area in a damaged panel. When the pointed end is used, this same hammer is called a pick hammer. A pick hammer is used to move a small amount of metal.

The hammer handle can be made of wood or fiberglass. Wood handles are the most common. The length of the handles can vary. A short handle may allow the entire hammer to be used inside a panel. On some panels, only the head of the hammer will fit into the repair area. In these instances, a long handle allows the hammer head to reach the damage.

The size of the hammer face can also vary. A large face is useful on a low-crown surface, while a small face is better suited for use on high-crown surfaces. The shape of the face can be circular or square. A square face can be used to straighten a body line. A circular face is used to straighten any area except a body line.

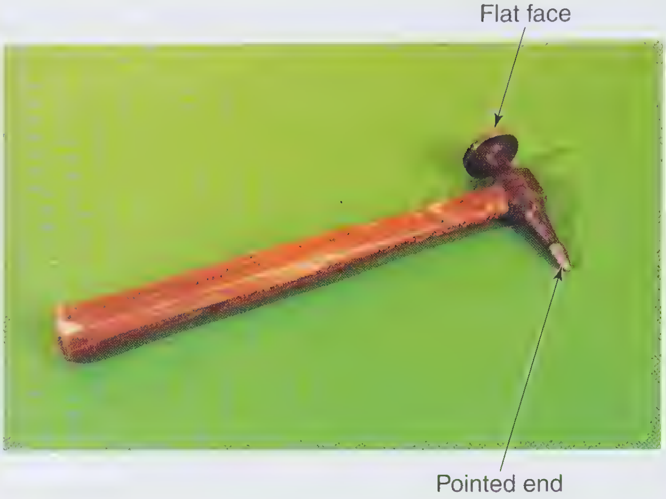


Figure 7-1. *A flat-faced dinging/picking hammer.*

The weight of the hammer head determines the amount of force it will produce. A heavy head strikes with more force than a light head. When overlapping panels are damaged, such as the edge or bottom of a door where the door skin folds over the door shell, a heavy hammer head will provide the force needed to move the panels. However, when finishing metal, too much force can be harmful, and a hammer with a lighter head should be used.

The pointed end of a body hammer, or pick hammer, can be sharp or blunt as shown in **Figure 7-2**. A sharp pick hammer will move a small amount of metal and can actually pierce a panel if used carelessly. A blunt pick hammer will move a larger amount of metal and is less likely to pierce metal.

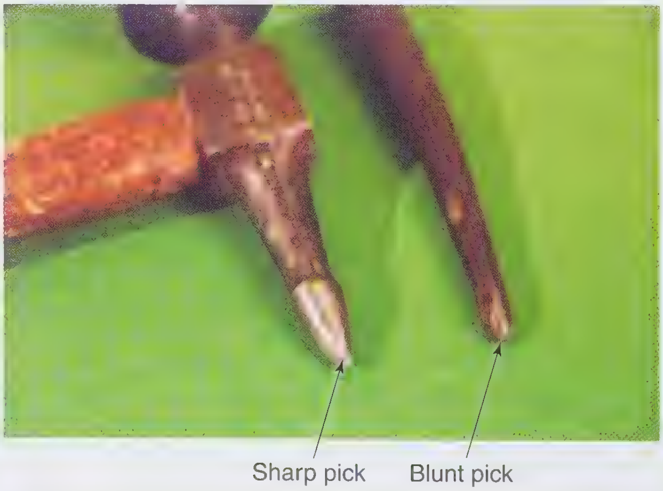


Figure 7-2. *Blunt and sharp pick hammers.*

The length of a pick hammer's shaft can also vary. A short pick hammer can often be placed inside a panel to raise low areas. However, if obstructions prevent a short hammer from being placed inside the panel, a pick hammer with a longer shaft may be able to reach the damage from outside the panel. A long pick hammer can be unwieldy when used on the outside of a panel.

Collision damage can cause a decrease in the original surface area of the metal. This surface area must be restored during repair. Increasing the surface area of metal is called ***stretching***. Stretching will restore the original dimensions to the damaged panel.

A stretching hammer is shown in **Figure 7-3**. Note that the face has a rounded, convex shape. When this type of hammer is used to hit a panel, only the center of the face will contact the metal. This concentrates the force of the blow on a relatively small area. When a stretching hammer is used with a dolly, the metal between the hammer and the dolly will stretch.

In some cases, collision damage will cause an increase in the surface area of the metal. Decreasing the surface area of metal during repair is called ***shrinking***. Shrinking will restore the original dimensions to the damaged panel. **Figure 7-4** shows a shrinking hammer. The serrations on the hammer face gather metal together when the hammer strikes the panel. The gathering of the metal decreases the surface area, shrinking the panel.

Other types of body hammers are available to repair specific types of damage. A chisel hammer can be used to repair a body line. A sharp chisel hammer is used to tap down high spots in a small-diameter body line. A blunt chisel hammer is used on a large-diameter body line.

A crown hammer has two high-crown surfaces, each crowned in the opposite direction. The crown hammer is useful when tapping down a ridge in a reverse crown. A crown hammer can also be used on the inside of a high-crown panel to raise a low spot. A hammer dolly is held in position against a panel and hit with another hammer. The handle allows the hammer dolly to be placed in a variety of positions, inside or outside a panel.

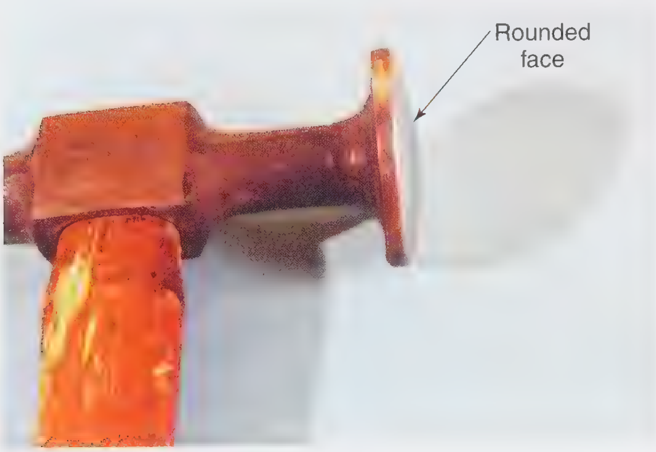


Figure 7-3. *A stretching hammer has a rounded face, concentrating the hammer force in a small area.*

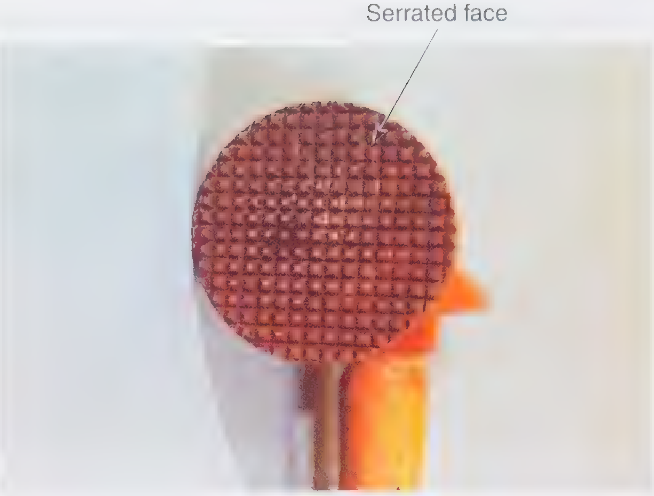


Figure 7-4. *A shrinking hammer has a serrated face.*

A door-skinning hammer is shaped to properly fold the hem flange when replacing a door skin. The door skin is the outer panel of a door. The hem flange is the area where the outer panel is folded over the door shell. Folding the hem flange without damaging the door skin takes considerable practice.

A ball peen hammer, while not actually a body hammer, can be used in panel repair. A light ball peen hammer can be used to hit a body chisel, body spoon, or hammer dolly.

Tapping with a body hammer is not done with the same motion as driving a nail with a carpenter's hammer. The body hammer is snapped with the wrist, not the elbow. The blows are rapid, at least one per second. Using a body hammer to rapidly and repeatedly tap damaged metal causes vibration. This vibration rearranges the position of the metal grains so the metal moves back to its original position. Only in situations where overlapping panels are damaged and significant force is required will a body hammer be used to drive down metal.

Hand placement on the hammer handle is critical. **Figure 7-5** shows how a hammer handle is normally held. A hand placed at the end of the handle will deliver the maximum force per blow. This may or may not be desired, depending on the nature of the damage. A hammer held in the choked position (hand close to the hammer's head) delivers less force. See **Figure 7-6**. The placement of the index finger allows more control and greater accuracy. The hammer would be held in this way when raising a small spot in a low-crown panel.

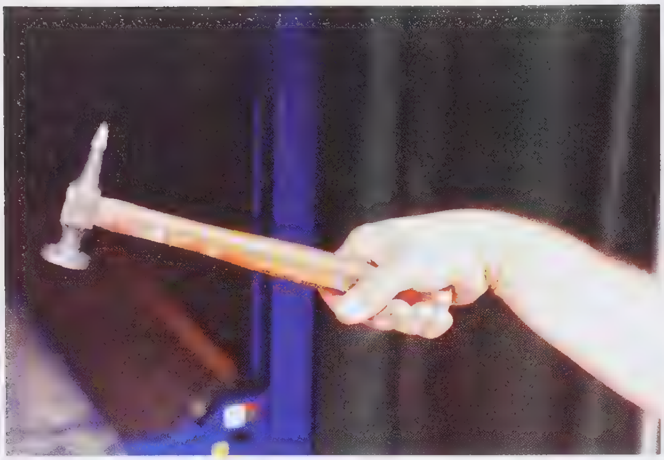


Figure 7-5. *When using a body hammer, swing from the wrist rather than the elbow.*

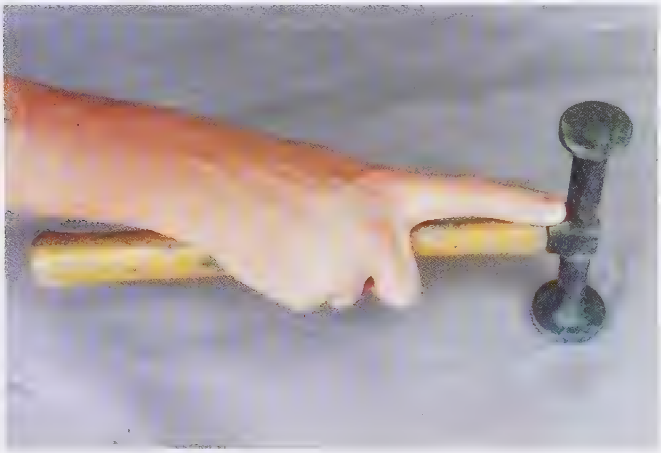


Figure 7-6. *The choked position with the finger placement shown produces accurate, low-power force.*

The hammer face should match the original (undamaged) contour of the panel as closely as possible. Matching the hammer face to the original contour of the panel is more important when repairing a reverse-crown panel than a low-crown panel. If the hammer face is so big that it contacts the undamaged portion of a reverse crown, the hammer will cause additional damage.

Never store hammers or other metal tools in damp areas. Dampness will cause the tools to rust. If the tools are rusted, dark spots show up on the surface of the metal. The tools can be cleaned up by sanding off the rust. Use 600-grit sandpaper to start and 1000-grit sandpaper to finish. The 1000-grit paper should leave a shiny, smooth surface on the hammer face. This shiny, smooth surface should be maintained.

Hammer faces are hard, but they can be damaged when used to hit something that is harder. **Figure 7-7** shows a new dinging hammer that was used to tap on MIG welds. The face of the hammer is nicked. If this nicked hammer were used to tap metal, the impression of the nicks would be left in the metal.

A dinging, stretching, or crown hammer face that has nicks can be repaired using a sheet of 80-grit sandpaper. Place the sandpaper on a hard, flat surface. Smooth the face of a dinging hammer by moving it over the sandpaper with flat strokes as shown in **Figure 7-8**. Use circular strokes when removing nicks from a stretching hammer and up-and-down strokes when smoothing a crown hammer. Once the nicks are removed, use progressively finer sandpapers to sand out the 80-grit scratches. After the 80-grit sandpaper, switch to 180-grit, 320-grit, 600-grit, and finally 1000-grit sandpaper.

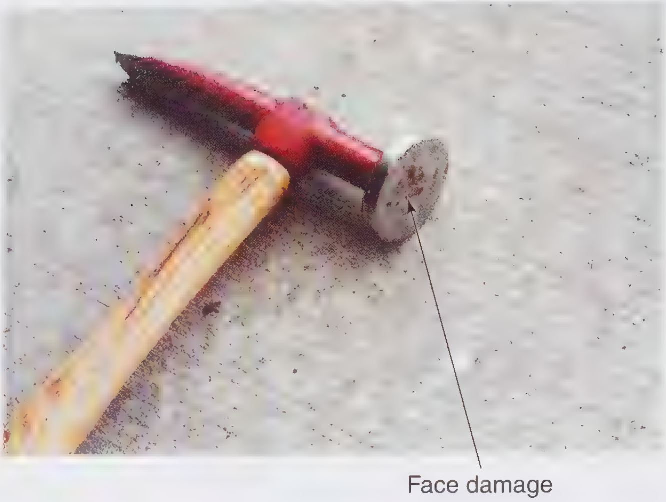


Figure 7-7. *The face of this dinging hammer is damaged.*

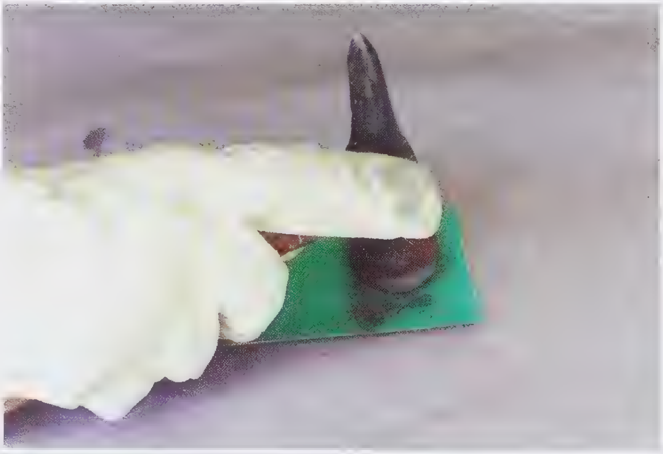


Figure 7-8. *The face of a dinging hammer can be repaired by smoothing it with sandpaper. Pass the hammer over the sandpaper with long, flat strokes.*

Wooden hammer handles can break or become loose. Broken handles should be replaced. A hammer with a loose handle should not be used until it is repaired. A wedge can be driven into the top of the wooden handle to spread the handle enough to eliminate the looseness. If this does not work, the handle should be replaced.

Dollies

Dollies are steel blocks that have various crowned surfaces. See **Figure 7-9**. The crown of the dolly should be matched to the crown of the panel being repaired. Dollies can be used to support the underside of a panel when tapping on the outside. Dollies can also be used to hit the damage either directly or indirectly. Direct hits occur when the dolly is used to hit and raise a low spot. Indirect hits occur when the dolly is held tightly against the back of a low spot and a hammer is used to tap an adjacent high spot. The vibration from the hammer will cause the dolly to rebound against the low spot.

A universal dolly is shown in Figure 7-9A. This dolly has high-crown and low-crown surfaces, as well as flat and chisel surfaces. A heel dolly is shown in Figure 7-9B. This dolly has both high-crown and flat surfaces. It also has a slight reverse-crown surface. A comma dolly also has a variety of crowns. See Figure 7-9C. A spoon dolly is shown in Figure 7-9D. This dolly has a long handle that allows it to be placed inside areas where a standard hand-held dolly could not reach. This dolly also has a very blunt chisel end, which can be used to move a large body line or a small-diameter, high-crown surface. To do this, the spoon dolly would be driven with a hammer.

A shrinking dolly has a serrated surface. The dolly is placed on the inside of a stretched panel so that it contacts the stretched metal. A hammer is used to tap on the outside of the panel, driving the stretched metal into the dolly serrations. The serrations gather the metal, decreasing the surface area of the panel.

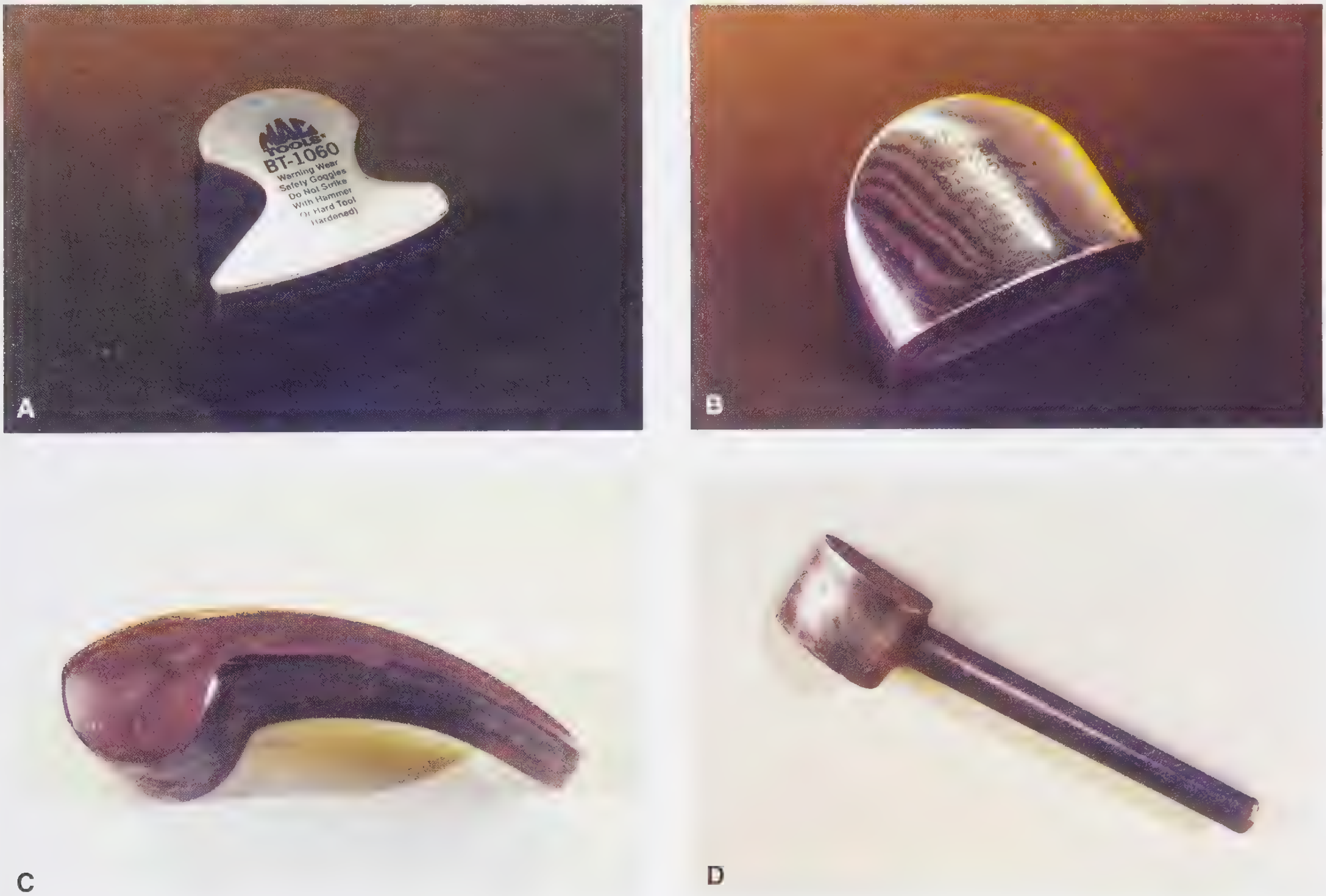

MAC TOOLS
BT-1060
Warning Wear Safety Goggles Do Not Strike With Hammer Or Hard Tool (Hardened)
A
B
C
D

Figure 7-9. *A—A universal dolly has many different surfaces. B—A heel dolly has high- and low-crown surfaces. C—A comma dolly has high-crown surfaces, as well as a chisel end. D—The spoon dolly's handle allows the spoon to be inserted inside panels.*

When a dolly is used, the surface of the dolly must have the same crown as the undamaged panel. If the dolly does not match the panel, additional damage can result as the panel is repaired. **Figure 7-10** shows how a dolly matches panel contour.

The working surface of a dolly can rust or be nicked. Dollies can be maintained in the same way as hammers. If a dolly surface is not the proper crown, it can be changed by grinding. For example, if the high-crown surface on a dolly does not match the contour of a panel, the surface of the dolly can be ground down until it matches the panel. After grinding, the grinding scratches can be removed by sanding.

Spoons

A ***spoon*** is used to spread out the force of a hammer blow. A dinging spoon is shown in use in **Figure 7-11**. The spoon is held by the handle, and the working face is placed against a high area on the panel. A ball peen hammer is used to tap the spoon.

Some spoons have a curved working face. Only a portion of the curved face should contact the high area. A spoon can also be used to adjust panel gaps. Spoon surfaces can become nicked or rusty. Maintain the working surface in the same way as you would hammers and dollies.

Picks

Pry picks, often simply called ***picks***, are shown in **Figure 7-12**. These tools are designed to be inserted inside a panel to raise low spots. A pry pick can have a sharp end or a blunt end. A sharp pick can raise a small area but is sharp enough to pierce the metal if misused. A blunt pick will raise larger areas and will not pierce the metal. The length of picks can also vary. A long pick has a greater reach than a short pick. Picks must have a surface to rest against for leverage. This resting surface must be stronger than the damage. If the damage is stronger than the resting surface, the resting surface will be distorted when leverage is applied to the pick.

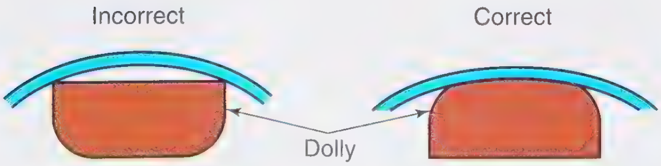


Figure 7-10. *The dolly's contour should match the contour of the undamaged panel.*

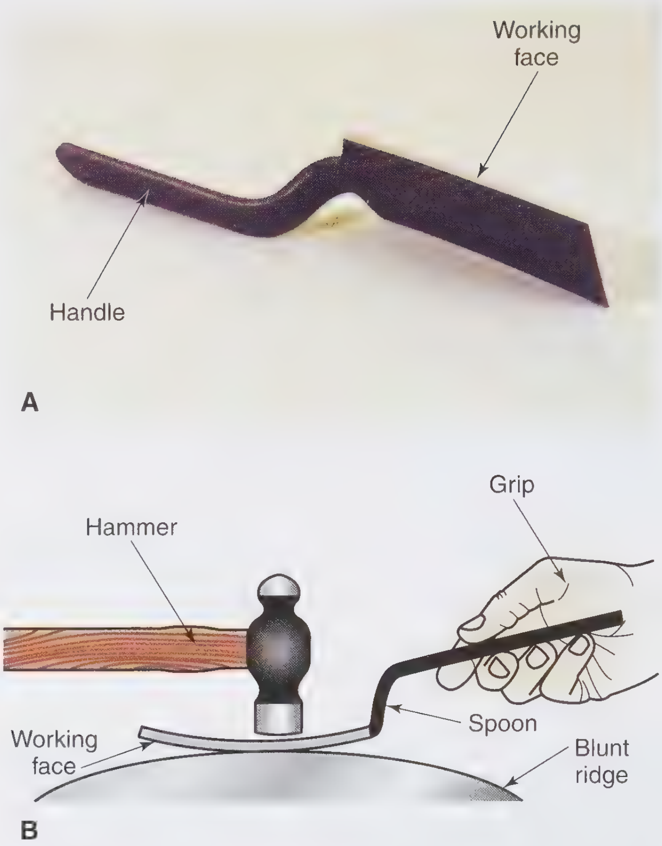


Figure 7-11. *A—A dinging spoon has a handle and a working face. B—Using a hammer to tap a dinging spoon.*

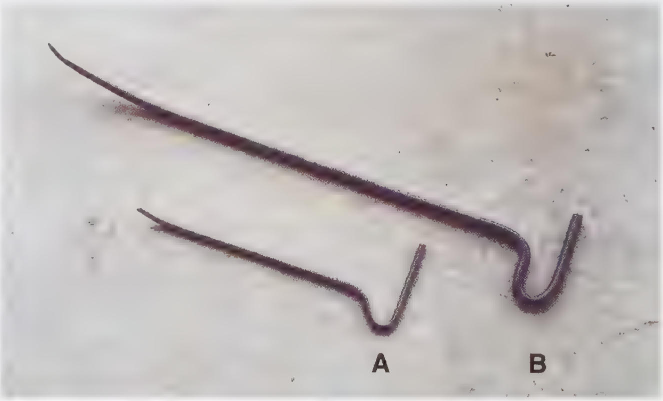


Figure 7-12. *Pry picks. A—This short pry pick has a blunt end. B—This long pry pick has a sharp end.*

When a pry pick is inserted into a panel, the technician cannot see where the point of the pick is located. To determine the location of the pick point, slightly raise an area with the pick and watch on the outside of the panel for the point. Adjust the location of the pick as needed to raise the low area. Gradually raise a dent by prying up slightly at several points in the dent. Raising the dent from a single point will stretch the metal, causing additional damage.

Slide Hammer

The ***slide hammer*** is useful for adjusting panels and raising damage. A ten-pound slide hammer with various attachments is shown in **Figure 7-13**. The attachments consist of several hooks and screws. The deep curved hooks are used to reach around obstructions. The part of the hook that contacts the metal is small and may stretch the metal. Therefore, care must be taken when using a hook. One use for a curved hook is to pull out damage on a wheel well. The curved hook reaches around the flange on the wheel well to apply force to the damage.

An L-shaped hook can fit into a small area, like the gap between a fender and a door. The L-shaped hook can pull out a damaged door edge. The left fender on the vehicle shown in **Figure 7-14** was hit in the front, moving the fender rearward. Opening the driver's door bent in the fender. The L-shaped hook is inserted between the fender and the door and is used to pull out the fender. Be careful. If the door or other panel has crown, the hook will not match the crown. Slide hammering with the flat surface of the hook on the crown may cause additional damage.

A notched hook can be used to grab a bolt or nut. A bolt and nut can be inserted into a hole in a damaged panel, such as the taillight hole in a damaged rear body panel. The notched hook is attached to the nut or bolt head, and the slide hammer is used to pull out the damage.

A screw attachment can also be used to pull panels. This method requires that holes be made in the low area of the damaged panel. Because this approach creates additional damage, it is not often used. However, if holes are made, the best way to create them is to punch them in the panel with an awl. This creates a slightly stronger hole edge than drilling. The screw attachment is turned into the hole and the slide hammer is used to pull the damage out.

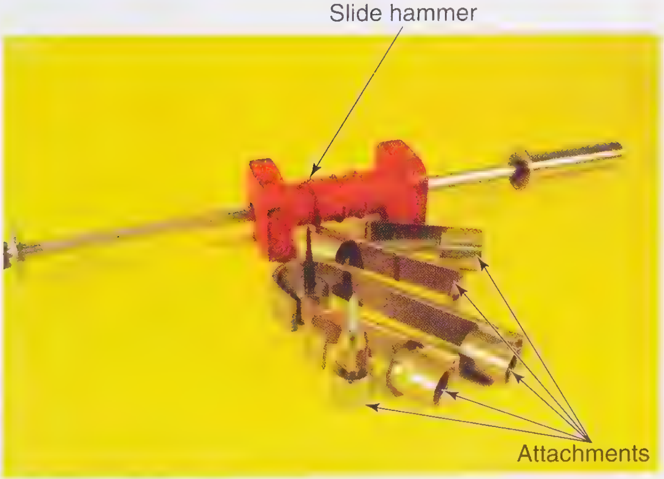


Figure 7-13. *A ten-pound slide hammer and various hooks.*

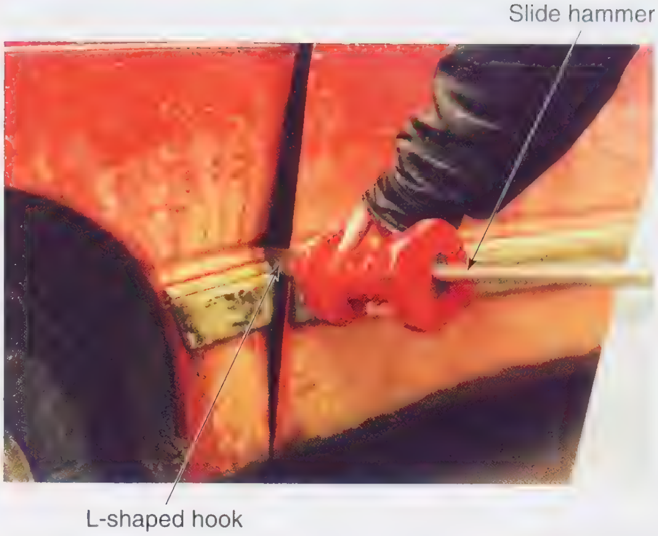


Figure 7-14. *This slide hammer is being used to pull out a fender edge.*

WARNING

Be careful when using a slide hammer. If your fingers are between the hammer and the shaft end, they will be injured when the hammer is pulled back against the handle.

Friction Jack

The ***friction jack***, also called a push-pull jack or a monkey on a stick, consists of an L-shaped rod and a jack head. As the friction jack's handle is pumped, the jack head moves along the rod. The jack head can be set up to move toward or away from the short leg of the rod.

The friction jack can be used to align panels and to push out minor damage. The friction jack can also function as an "extra hand" when replacing or aligning panels. For example, when replacing a fender on a vehicle with a bolted-in-place radiator support, the friction jack's rod can be set up on the cowl and the head can be positioned to hold the radiator support in place. When the damaged fender is removed, the jack will prevent the radiator support from jumping out of position. See **Figure 7-15**.

To push one surface away from another, such as when spreading fenders in the engine compartment, install the friction jack head on the rod so it moves away from the short leg of the rod. Place the rod's short leg against one fender and the head against the other fender. Pumping the handle will push the fenders apart.

To pull two panels together, install the friction jack head on the rod so it moves toward the short leg of the rod. The short leg can be installed in a hole in the cowl

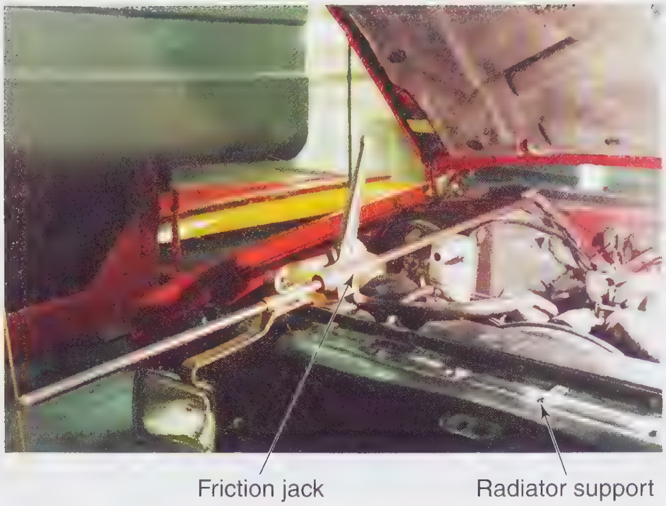


Figure 7-15. *This friction jack is used to position a vehicle's fender.*

and the head can be positioned on the radiator support. Pumping the jack handle will pull the radiator support into place.

> **WORKING SMART**
>
> **Because the contact surfaces of the rod and friction head are small, they concentrate the force of a push or pull in a small area and can cause panel damage. A block of wood placed between the panel and the rod or friction head contact surface will help minimize damage.**

Alignment Bar

Another tool that can be used to position panels is an ***alignment bar***. See **Figure 7-16**. The bottom of the alignment bar has a foot. The foot is braced on a solid, undamaged surface of the vehicle. A chain is attached to the damaged portion of the vehicle and to a point on the alignment bar above the foot. The damage is then moved as the technician pulls or pushes the top of the alignment bar away from the vehicle. The power of the pull increases as the distance between the attachment on the alignment bar and the top of the bar increases.

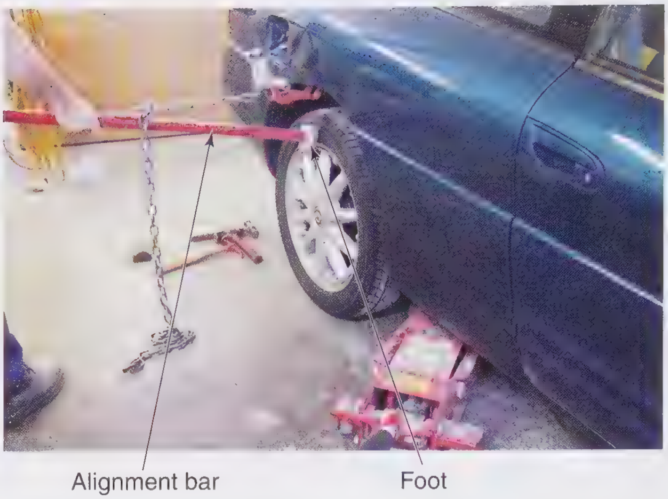


Figure 7-16. *As the technician pushes down on the bar, the damage moves out.*

Door Removal and Alignment Tools

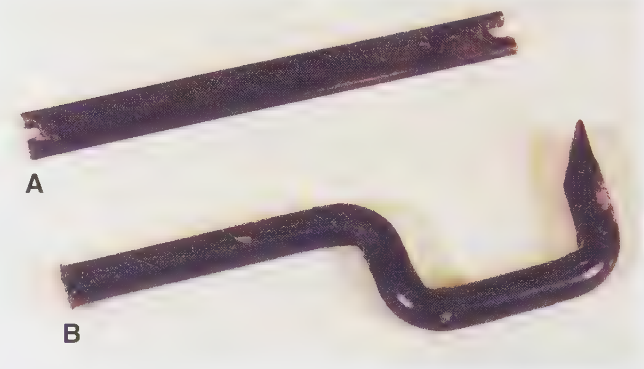


Figure 7-17. *These tools are used to remove the pins in a door hinge. A—The notches in the bar fit on the shoulder of the pin. The bar is then hit with a hammer to drive the pin out. B—The punch tool is hit with a hammer to drive the pin out.*

Doors with welded-on hinges can be removed by tapping out the hinge pins. The tools used to accomplish this task are shown in **Figure 7-17**. In most cases, the upper hinge pin is tapped down and the bottom hinge pin is tapped up. The pin removal punch has an offset to allow it to reach around obstructions. The punch is placed on the pointed tip of the pin and hit with a hammer to start driving the pin from the hinge. Once the pin begins to move, the notched strap is used to finish removal. The notch is placed under the wide end of the pin. A hammer is then used to strike the tool, driving the pin out.

Some door hinges have detachable springs. A small spring compressor is used to remove and install these springs. See **Figure 7-18**. To remove a spring, position the compressor on the spring and use a wrench to tighten the compressor's bolt. This will bring the compressor's jaws together and compress the spring so it can be removed from the hinge. When installing a spring, compress the spring and position it in the hinge.

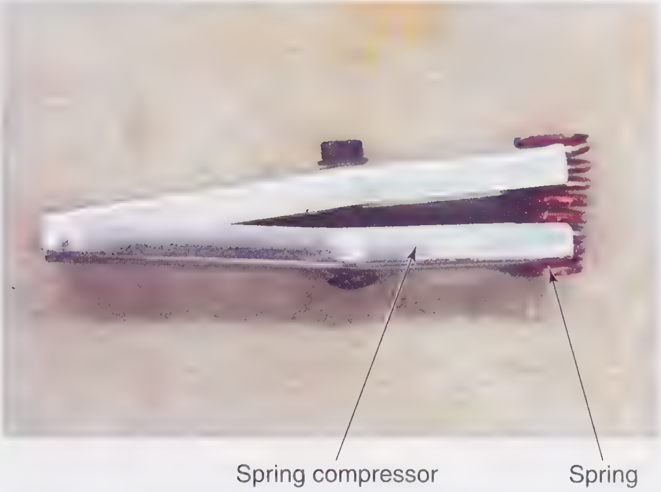


Figure 7-18. *This door hinge spring compressor is holding a spring in the compressed position for installation.*

Then loosen the compressor's bolt, opening the jaws and allowing the spring to expand. When the spring is properly set in the hinge, remove the compressor.

Doors with welded-on hinges can be aligned with a door adjust bar as shown in **Figure 7-19**. The bar's striker is hooked into the door latch and the leverage end of the bar rests on the vehicle's striker. Positioning the bar to push upward will lift the rear of the door. Positioning the bar to pull downward will lower the rear of the door.

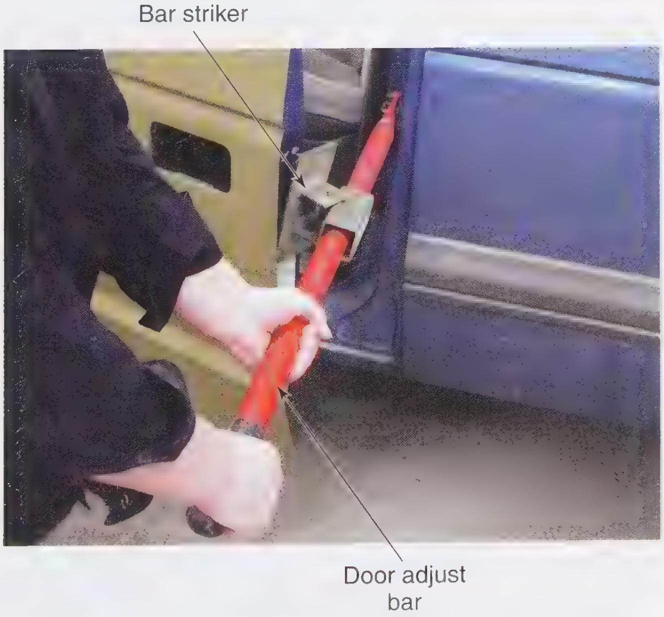


Figure 7-19. *This bar is attached to the door latch and pivots on the striker, adjusting the door up or down.*

Body Chisel

Figure 7-20 shows a ***body chisel***. The wide face is not used to cut metal; instead it is used to raise a damaged body line. The chisel is placed on the damaged body line and hit with a hammer. Notice that this chisel has masking tape over the working edge. This is to prevent the chisel from cutting into the metal. The plastic shield on the handle helps protect the technician's hands. As with all tools that are intended to be struck with hammers, the striking surface should be dressed (by grinding or filing) if it becomes mushroomed. A mushroomed striking surface may chip.

Metal Files

Metal files are used to identify high and low areas in a panel. Two types of metal files are shown in **Figure 7-21**. The wooden handle file is not adjustable. The aluminum-handled file can be adjusted by turning the center turnbuckle.

The metal file should be pushed away from your body. The idea is to float the file over the metal surface, snagging it on the high spots but not cutting the metal. No contact with the metal should take place as you pull back the file. The file should always be moved perpendicular to the crown of the panel. Adjust the turnbuckle on an aluminum-handled file to make the file flat for low-crown and single-crown panels. Long strokes, up to 3' (0.91 m) in length, can be used on low-crown or single-crown panels. When using a nonadjustable wooden-handled file on double-crown panels, file in short strokes about 1" (25 mm) long. File perpendicular to one

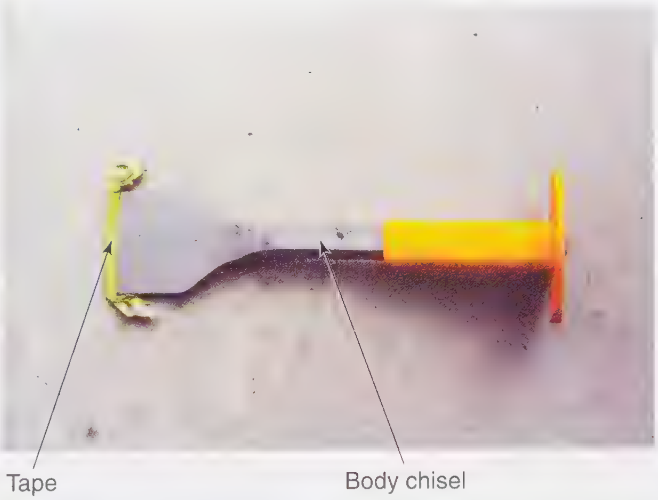


Figure 7-20. *This body chisel has masking tape over the cutting edge. The tape will help protect the metal in the damaged body line.*

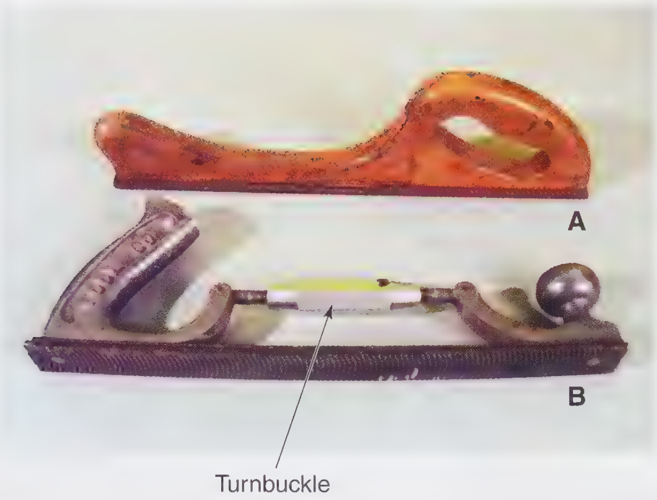


Figure 7-21. *A—A wooden-handled body file. B—An adjustable file can be set to conform to different crowns.*

crown in the panel; then shift and file perpendicular to the other crown. When using an aluminum-handled file on a double-crown panel, adjust the file to fit one of the crowns and file in short strokes. Then, adjust the file to fit the other crown and continue filing in short strokes.

Bull's-Eye Pick

A ***bull's-eye pick***, **Figure 7-22**, can make raising low spots much easier. The tool's bull's-eye is placed on the outside of the panel, directly over a low spot. Moving the handle causes the pick to hit the low spot on the inside of the panel. The picking is accurate. This tool works well on a panel with good access to the inside, such as a fender with the fender liner removed. A panel with limited inside access, such as a door or a quarter panel ahead of the rear wheel house, would not be a good place to use this tool.

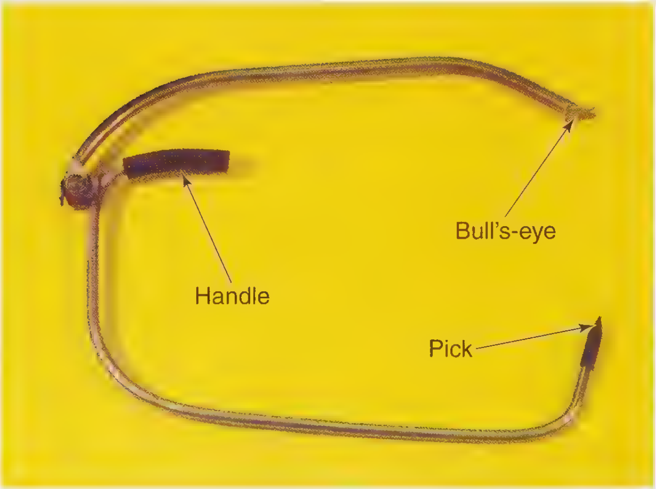


Figure 7-22. *Blind picking is much easier with a bull's-eye pick.*

Panel Flanger

When welded panels are replaced, a flange, or offset, is occasionally made in what remains of the original panel. The flange allows the replacement panel to set on the offset so it is flush with the original panel. The replacement panel is then welded to the flange. A ***panel flanger*** can be used to make flanges. See **Figure 7-23**. A flange is created as the panel flanger is clamped to the panel.

Hand Punch

Another tool used in welded panel replacement is the hand punch, **Figure 7-24**. The ***hand punch*** makes 5/16" (8 mm) diameter holes in sheet metal. This is the proper size for plug welds. The throat of the hand punch does not have great depth, so this tool can only be used to make holes near the edge of a panel.

Filler Tools

Filler tools are used to apply and level body filler. **Figure 7-25** shows a plastic ***mixing board*** designed to be used when mixing body filler. Never mix filler on cardboard or any other absorbent surface. Because cardboard will absorb some of the material in the filler, the filler may not function as intended. Also, a cardboard

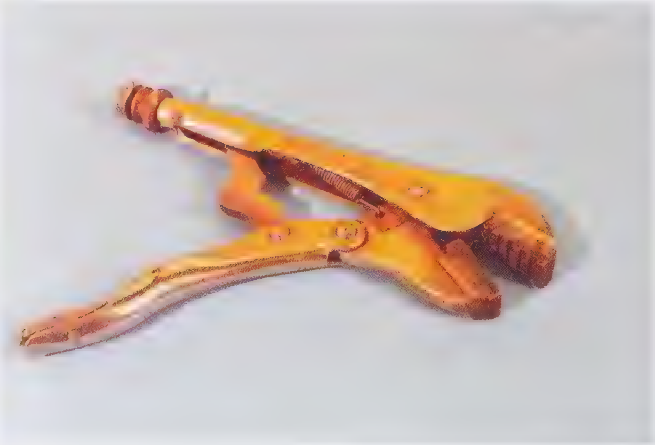


Figure 7-23. *The jaws of these pliers bend a step, or flange, in a sheet metal panel.*

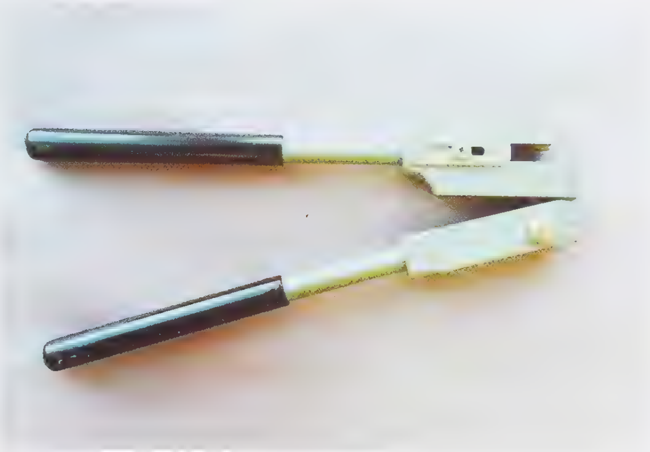


Figure 7-24. *This hand punch makes 5/16" holes in sheet metal.*

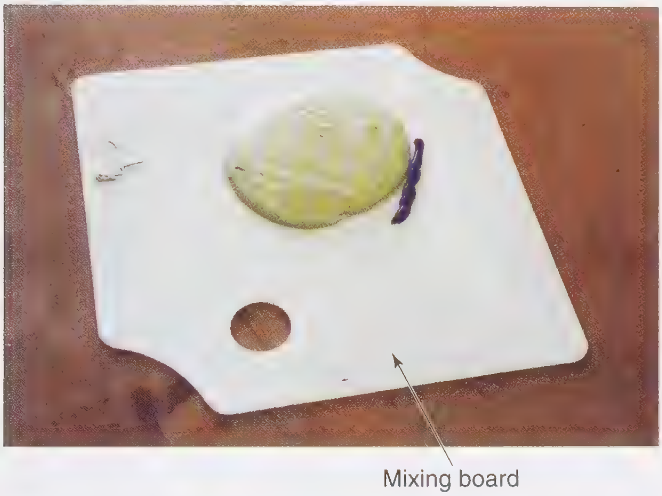


Figure 7-25. *A plastic board can be used to mix body filler and hardener.*

surface may contaminate the filler. Always mix filler on a clean, impermeable surface, such as plastic or metal. The mixing board should be cleaned after each use. Mixing on a dirty board will allow chunks of hardened filler to be mixed in with the new filler. This will cause streaks in the new filler as it is applied. The filler and hardener should be mixed with a clean paint stick. Always use a clean stick to remove filler from the can.

The mixed filler is applied to the low area with a ***spreader***. Plastic spreaders are available in a variety of sizes. See **Figure 7-26**. The spreader should be clean. A spreader covered with dried filler will not lay down a smooth layer of filler. The edge of the spreader should be straight and smooth. Any irregularities in the edge of the spreader will be transferred to the filler. Ragged filler with gouges will take extra time to sand and may need to be refilled. A spreader with a ragged or torn edge should be replaced.

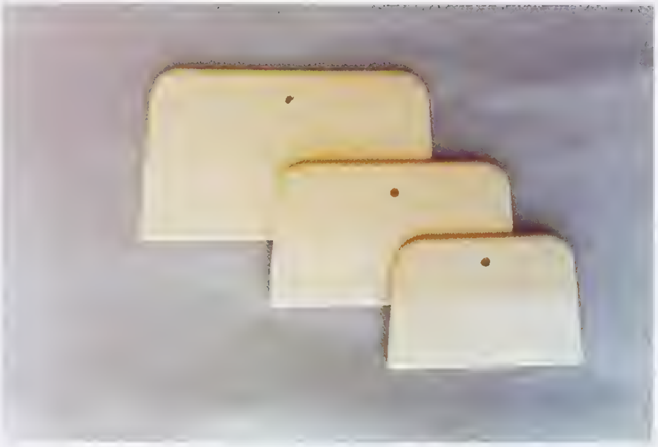


Figure 7-26. *Various sizes of filler spreaders.*

Shaping and Sanding Tools

Hand tools used to level filler include a surform tool, a long board, a sanding block, and a sanding stick. When filler has partially cured, it can be leveled with a ***surform tool***, or cheese grater. A surform tool, **Figure 7-27**, has a serrated working face. The serrations cut into the semi-cured filler to quickly remove excess material. The tool can be used in a holder or by itself. The surform tool can be cleaned with a wire brush after use.

There are two ways to sand cured filler: rough sanding and final sanding. Rough sanding removes excess filler with 40-grit sandpaper. As the filler is sanded, a tapered edge, called a featheredge, will be formed. Once the featheredge appears all the way around the filler, rough sanding is complete and final

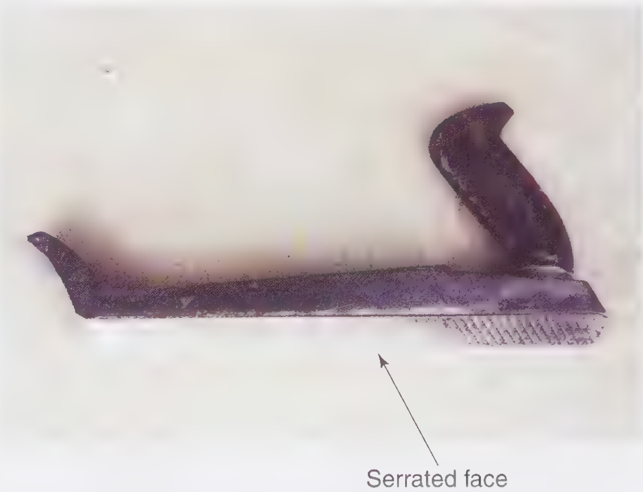


Figure 7-27. *A cheese grater can be used to quickly remove excess filler. Note the serrated work face.*

sanding should be started. During final sanding, 80- and 180-grit sandpaper is used to remove the deep scratches left in the filler from the 40-grit sandpaper and to increase the taper on the featheredge.

There are several tools used to sand filler. It is important that the filler be sanded to exactly the same height as the surrounding metal. Any deviation will be visible after the panel is painted. If a sanding tool's surface can be compressed, even slightly, the tool may sand the filler a little deeper than the surrounding metal. For this reason, a sanding tool that has a soft, compressible surface for mounting sandpaper should never be used when final sanding filler. A sanding tool with a hard mounting surface is required.

Long boards can be used to sand filler on both low-crown and high-crown surfaces. The long boards shown in **Figure 7-28** use standard 2 3/4" (7 cm) wide sandpaper. Precut sandpaper for a long board is 17 1/2" (30 cm) long. The sandpaper is secured to the wooden-handled board with clips. The paper must be installed tightly. Loose paper will tear when sanding. Some plastic long boards use adhesive-backed sandpaper rather than clips. A long board that uses Velcro-backed sandpaper is also available.

The adjustable long board shown in **Figure 7-29** has three removable rods. With all the rods in place, this board is rigid. If one of the rods is removed, the long board is less rigid. If all three rods are removed, the long board bends easily to conform to a crown. This is an important aid in sanding body filler.

Figure 7-30 shows flexible long boards. These boards can bend slightly to conform to a crown. Regardless of the type used, the long board should be held perpendicular to the crown of the panel and moved so it sands with the crown. When sanding a high-crown surface, the board should be tilted as shown in **Figure 7-31**. Note that only the narrow edge of the board contacts the work surface. This will help prevent the board from cutting a flat spot in the filler.

Sanding blocks, **Figure 7-32**, are also used to sand body filler. These blocks accept standard-width sandpaper. However, the paper must be cut to the proper length. To install sandpaper, lift the slit at either end of the block and slide the sandpaper into the opening. There are spikes inside the slit that will pierce the sandpaper, holding it in place. Make sure the sandpaper is installed tightly. In addition to installing sandpaper over the flat surface, it can also be installed over the curved surface of the sanding block as shown in

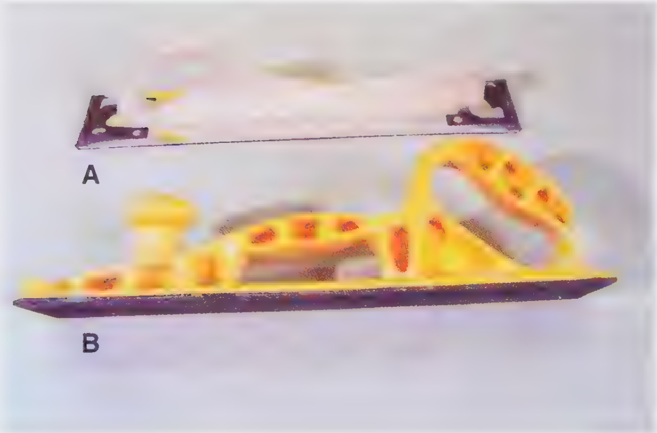


Figure 7-28. *A—The wooden-handled sanding board has clips to hold the sandpaper B—The plastic handle sanding board uses adhesive-backed sandpaper.*

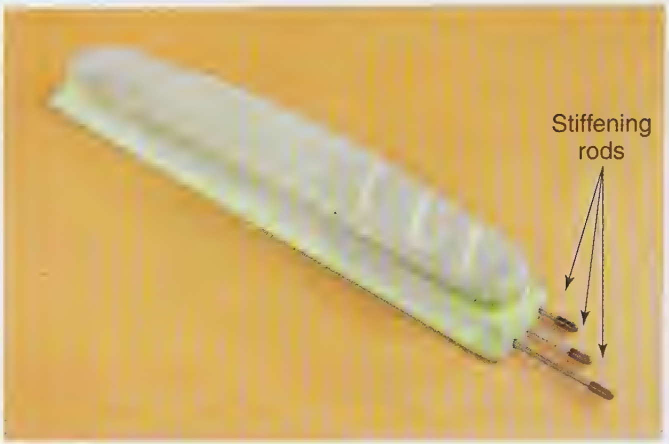


Figure 7-29. *Removing rods makes this long board more flexible.*

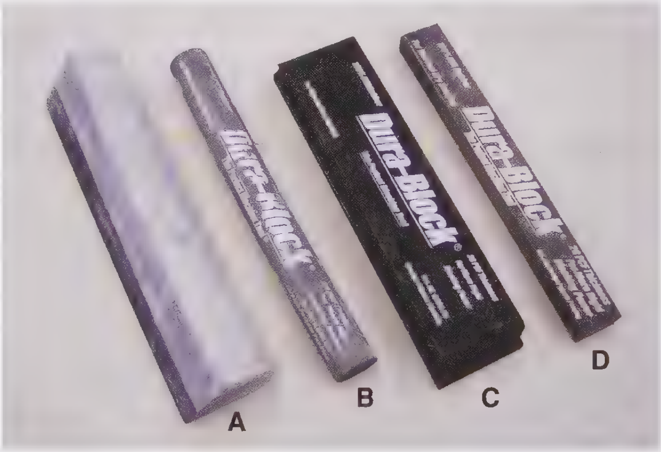


Figure 7-30. *A—A teardrop-shaped long board. The narrow end can be used in a body line, and the rounded end is useful when sanding a reverse crown. B—This sander is round in cross section. It can conform to a small reverse crown. C—This long board is relatively wide and is used when sanding a low-crown area. D—This narrow long board can bend enough to sand a double crown, such as a motorcycle tank.*

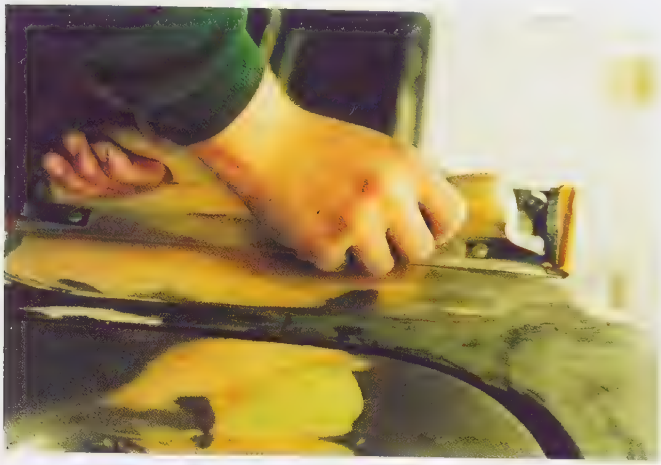


Figure 7-31. *The sanding board should be tilted on edge to sand a high-crown surface.*

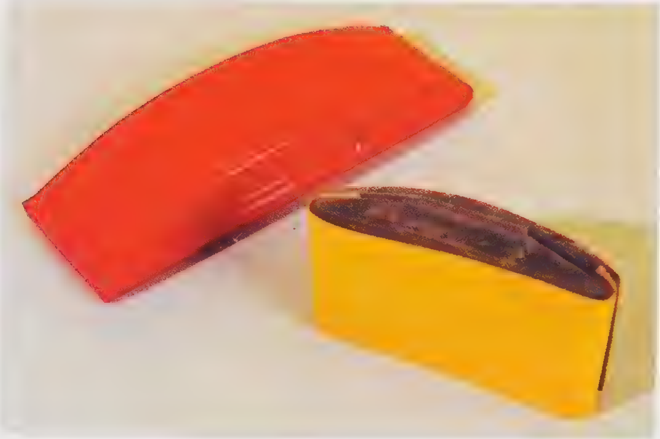


Figure 7-32. *Sanding blocks may vary in length. Use the length best suited for the job at hand.*

Figure 7-33. This allows the block to be used to sand reverse-crown surfaces.

Figure 7-34 shows a teardrop sander. The sharp end of the teardrop sander can be used to sand a body line. The rounded end can be used to sand a reverse crown. Because this sander is short, it can be used to reshape a double-crown area if short sanding strokes are used.

A ***sanding stick*** is the tool that should be used to final sand filler. The sanding stick is simply a flat paint stick wrapped in sandpaper. To be useful, the stick must be absolutely flat, **Figure 7-35**. If adhesive-backed sandpaper is used, the paper is simply applied to the stick. If standard sandpaper is used (no adhesive), the paper must be wrapped tightly around the stick. On high-crown surfaces, the stick can be used on its edge. On low-crown surfaces, the stick can be used flat. The stick has enough flexibility to be used on a double-crown surface.

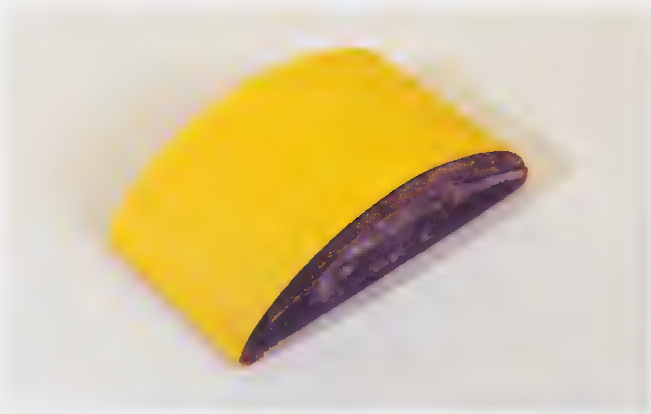


Figure 7-33. *Sandpaper can be installed on the curved surface of the sanding block when working on curved panels.*

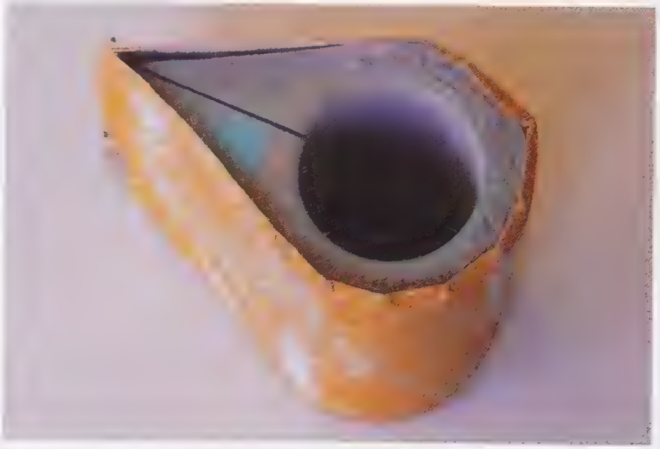


Figure 7-34. *This teardrop sander can be used on body lines and reverse crowns.*

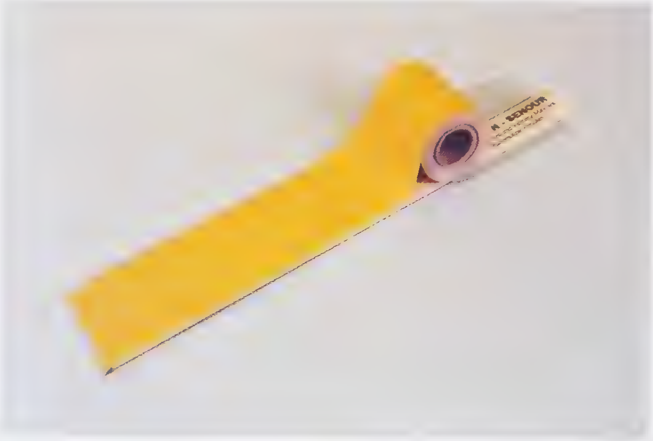


Figure 7-35. *A flat paint stick can be used for final sanding. Adhesive-backed sandpaper can be installed on the stick.*

PVC pipe can be used when sanding reverse-crown surfaces, as well as high-crown surfaces and body lines. The sandpaper is wrapped around or attached to the pipe. PVC pipe is available in a variety of sizes. Virtually any automotive reverse crown can be matched with PVC pipe.

Repairing a damaged body line with filler can be difficult and frustrating. There are two main problems:

- Sanding the body line straight.
- Reforming the exact contour of the body line.

A tool that will sand a straight and properly contoured body line in filler is shown in **Figure 7-36**. This tool consists of two parts, a conformable sander and a guide. The base of the conformable sander is set into an undamaged portion of the body line. The sander base is then adjusted to take on the shape of the undamaged body line. Sandpaper is attached to the sander base. A special tool is used to press the sandpaper to the base so the exact contour of the body line is maintained with the sandpaper.

The guide is attached to the panel with suction cups and is adjusted so the sander, which slides along the top of the guide, is in the correct position to create the body line. Once the guide has been positioned and adjusted, sanding the filler to form the body line is easy. Although this tool requires planning and takes time to set up, it will make body line sanding faster and less frustrating.

Another type of body line sander is shown in **Figure 7-37**. This type of sander, which is available in 5" (13 cm), 10" (25 cm), and 15" (38 cm) lengths, is molded to fit the body lines of several different vehicles. These sanders are available in sets for domestic and imported vehicles. The sandpaper is attached to the surface of the sander that matches the undamaged contour of the body line. The sander is then used to cut the correct contour in the body filler. This type of sander works best if it can span the body filler and rest on the undamaged portions of the body. If you are sanding a patch of body filler that is wider than the sander, use the largest sander available and be careful to cut a straight body line in the filler. Using the proper length sander will help prevent you from sanding a crooked line.

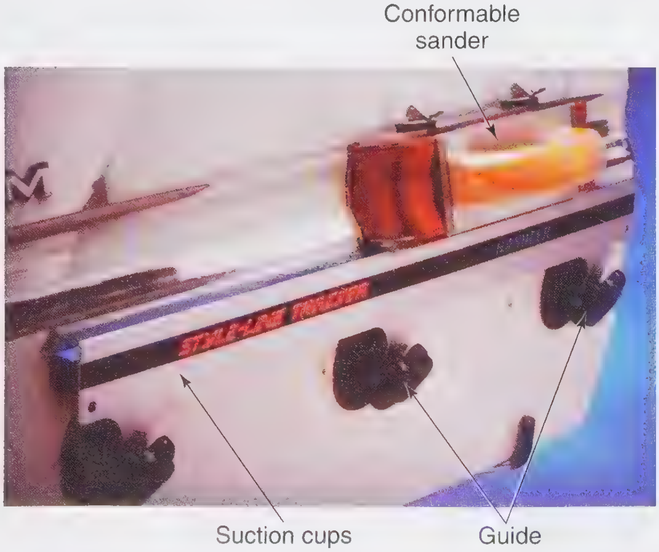


Figure 7-36. *The contour sander is adjusted to shape a duplicate of the undamaged body line. The suction cups require a smooth, painted surface for attachment. (Style-Line Corp.)*

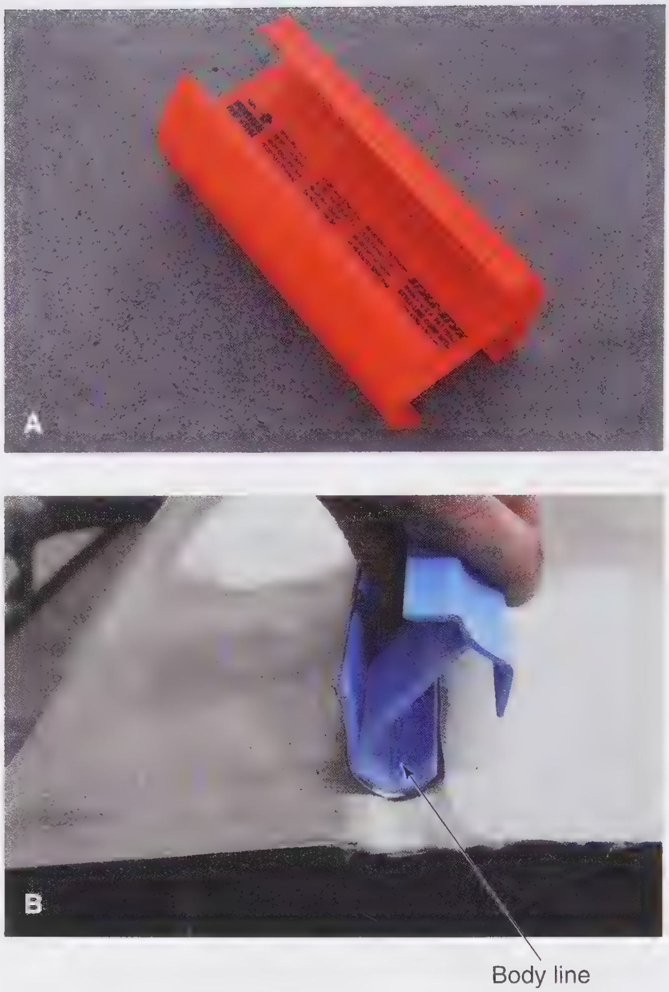


Figure 7-37. *A—Body line sander. B—Body line sander in use.*

Cable-Tensioning Devices

A cable-tensioning device attached to a strong base can be used to lengthen a panel. **Figure 7-38** shows a cable-tensioning device known as a ***come-along*** attached to a ***power post***, which serves as a base for the come-along. The come-along's cable is let out to reach the

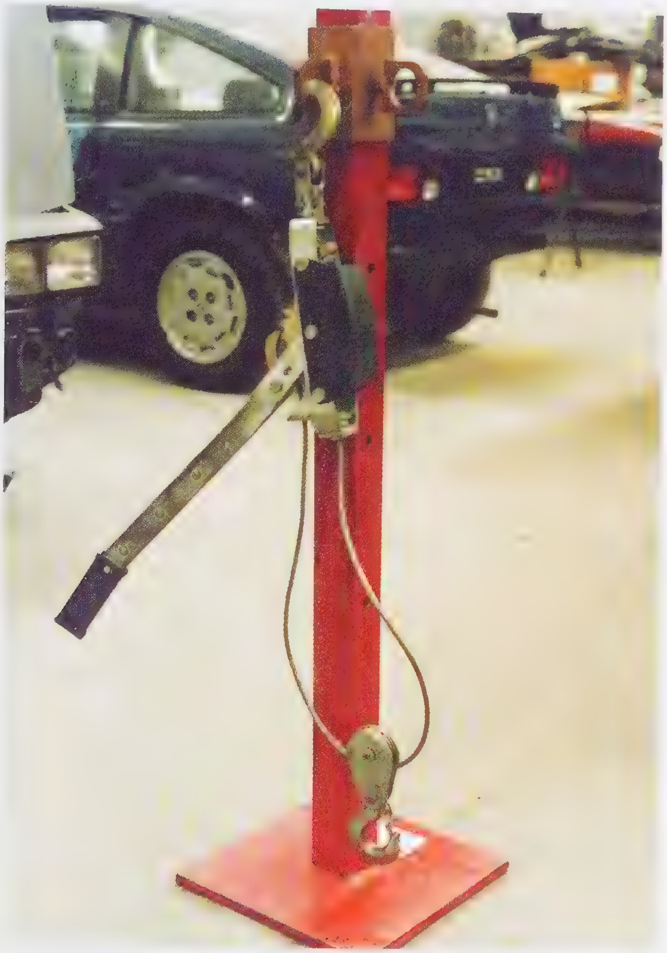


Figure 7-38. *This come-along is attached to a power post. The post can be anchored to a floor pot to hold it in place.*

damaged panel. As the come-along's ratcheting handle is pumped, the cable is pulled back in. As the cable is pulled in, it will pull on the damaged panel. This pull creates tension, which will lengthen the damaged panel.

The power post is designed to be chained to floor pots. ***Floor pots*** are anchors embedded in the floor. See **Figure 7-39**. When using a come-along and a power post, the vehicle should be anchored to prevent it from moving. When the come-along handle is pumped, only the damage will move because the post and vehicle are immobile.

Panel Repair Power Tools

Panel repair power tools are used to cut metal, remove paint and metal, and sand body filler. They make the technician's job easier and reduce the time it takes to complete many repairs. The following sections detail the most common power tools used in nonstructural panel repair.

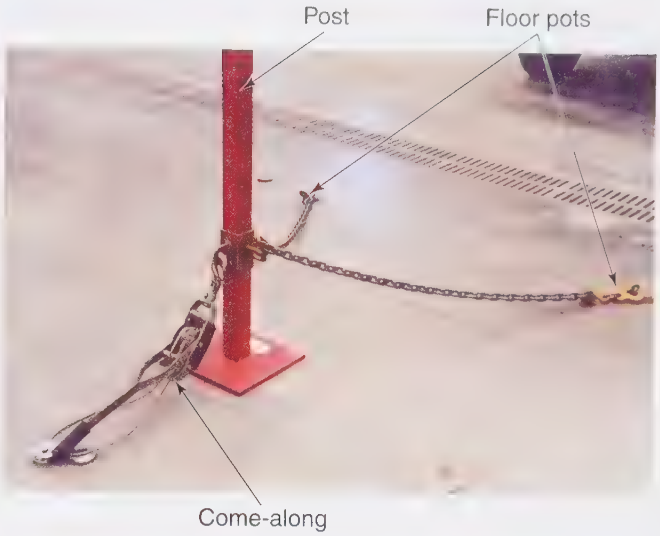


Figure 7-39. *Floor pots being used to hold a power post in place.*

Grinder

A ***grinder*** is used to remove metal and paint. The grinder spins a coarse abrasive disk at a high speed. A flat backing plate supports the disk. The backing plate is slightly smaller than the disk, so the edge of the backing plate will not contact the work surface.

In operation, the grinder is held at an angle so that only the upper 1" (25.4 mm) of the disk contacts the metal. See **Figure 7-40**.

Grinding produces sparks. These sparks can pit automotive glass and burn upholstery. Position the grinder so that the sparks fly away from the vehicle.

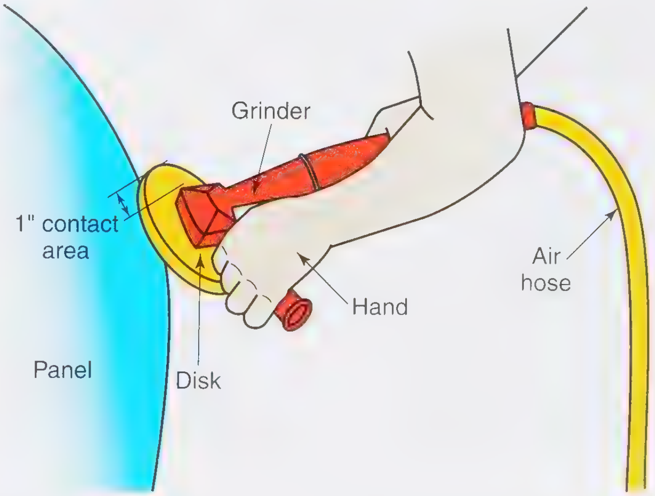


Figure 7-40. *Only 1" of the grinder's disc should contact the panel.*

Move the grinder perpendicular to the crown of the panel, **Figure 7-41**.

As the grinder is moved, it will leave a trail of scratches in the metal. One pass over the metal, which removes paint, is called buffing. Two passes over the same area—one pass from right to left and the other from left to right—is called cross cutting. Cross cutting removes paint and metal. Both buffing and cross cutting produce heat, but cross cutting produces more heat than buffing. In some types of metal repair, heat may aid in panel straightening. However, excessive heat can cause additional damage. Excessive heat is often seen as blue spots in the bare metal. Too many passes with the grinder or moving too slowly when grinding will warp the panel. Not moving the grinder at all will make a hole in the panel.

Air File

An ***air file*** is used to sand filler. See **Figure 7-42**. There are two basic types of air files: straight-line air files and orbital air files. A straight-line air file moves a rectangular shoe (the flat surface to which the sandpaper is attached) in a back-and-forth motion. An orbital air file, on the other hand, moves its shoe in an oscillating pattern.

The sandpaper used on an air file may have an adhesive backing or it may be clipped in place on the file shoe. Coarse grades of sandpaper are stiff and may break when bent around the shoe to the clips. If the sandpaper is loose on the shoe, it will tear. The shoes on air files are aluminum and the ends are easily bent.

An air file is used in the same way as a long board. The file is held perpendicular to the crown of the panel and moved so it sands with the crown. If a high crown is sanded, the air file can be tipped on edge. If the shoe has a soft backing, it should not be used for finish sanding.

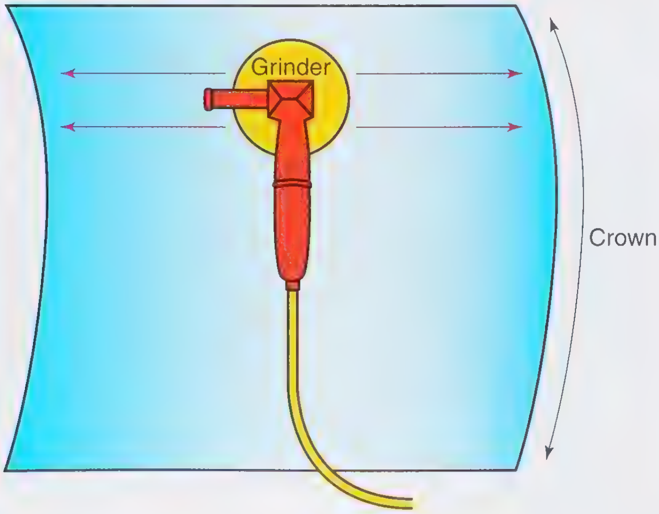


Figure 7-41. *Grinder movement should be perpendicular to the crown of a panel.*

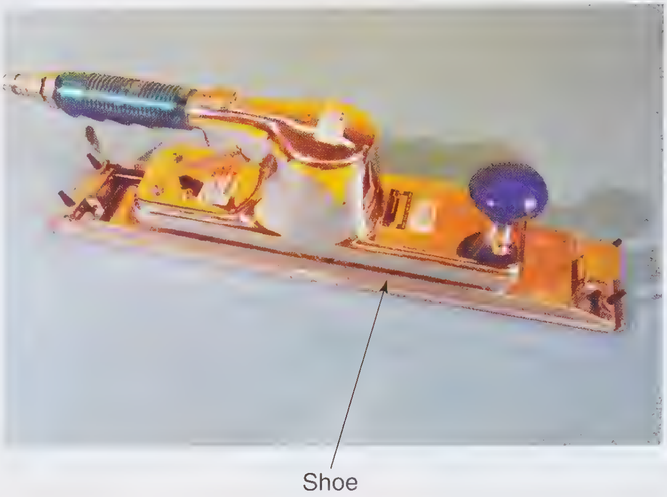


Figure 7-42. *An orbital air file has a rectangular shoe.*

Orbital Sander

An ***orbital sander***, also known as a mud hog, is shown in **Figure 7-43**. The orbital sander spins a coarse disk at a high speed. This tool will rapidly sand filler. The disk on this particular orbital sander is 7" in diameter. The orbital sander is moved so it sands with the crown.

To be effective, the disk should span the fill area. In this way, the edges of the disk rest on undamaged metal. If the fill area is wider than the disk, the edge of the disk may dig too deeply into the filler.

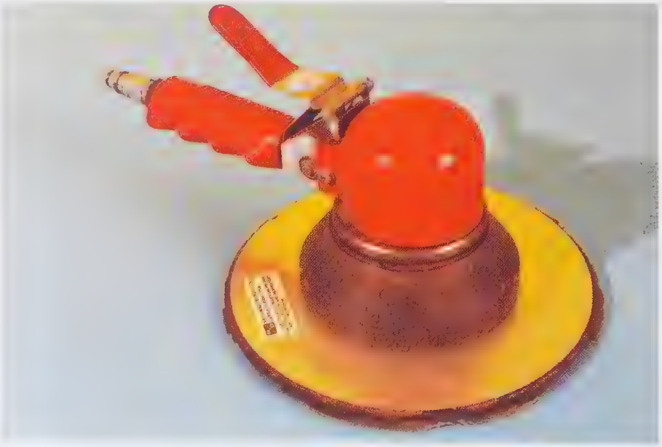


Figure 7-43. *This orbital sander can be used to rough sand body filler.*

The orbital sander can be difficult to control. Always have a firm grip on it before pulling the trigger. The orbital sander should be used to roughly shape the filler. A sanding stick should then be used for finish sanding.

Spot Weld Cutters

Spot weld cutters are shown in **Figure 7-44**. These bits are used to drill out spot welds, a very common task in welded panel replacement.

To drill out a spot weld, first identify all spot welds. Spot welds look like 5/16" (8 mm) circles in the metal. They are usually located along the panel edges. Center punch the spot weld. Then use a 1/8" (3 mm) bit to make a pilot hole. If the underlying panel is going to be reused, do not drill through it. Stop drilling the pilot hole as soon as the upper panel has been penetrated. After drilling the pilot hole, use a spot weld cutter bit to drill out the weld. The depth of cut can be adjusted on a hole-type spot weld cutter. The screw at the end of the arbor is turned in or out to adjust the depth of cut. After adjusting the depth of cut, install the spot cutter in the drill, center the cutter in the pilot hole, and drill out the spot weld.

Always keep the cutter bit at a right angle to the panel. The cutter bit teeth are easily broken if misalignment occurs. If the spot weld is not flat, the ragged edge of the weld may cause the teeth to snap off the bit. Do not use a hole-type spot weld cutter bit that has broken teeth.

The process of center punching, drilling a pilot hole, and then cutting out the weld may seem tedious, but it gives the best results when using a drill. Skipping step one or two will lead to the cutter bit "walking off" and may produce broken teeth. Highly productive technicians have two drills, one with a 1/8" (3 mm) bit installed and one with a spot weld cutter installed. In this way, they do not have to waste time changing bits.

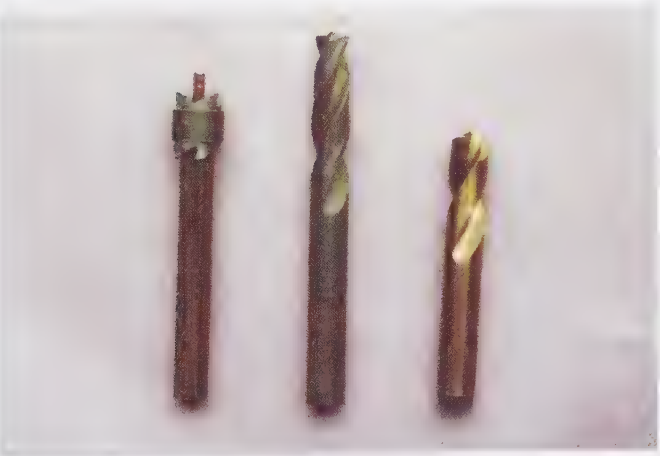


Figure 7-44. *Spot-weld cutter bits. A hole-type spot weld cutter is on the left.*

Another spot weld removal tool is shown in **Figure 7-45**. This is a dedicated spot weld cutter. The tool is air-powered and the depth of the cut is adjustable. This tool does not require a pilot hole. Instead, it clamps in place and will not walk off the panel.

Air Punch/Flanger

An ***air punch/flanger*** can be used to cut 5/16" (8 mm) diameter holes along the edge of a panel. The holes can be used to make plug welds. The flanger portion of this tool crimps a step at the edge of a panel. The stepped area is called a flange. **Figure 7-46** shows an air punch/flanger tool.

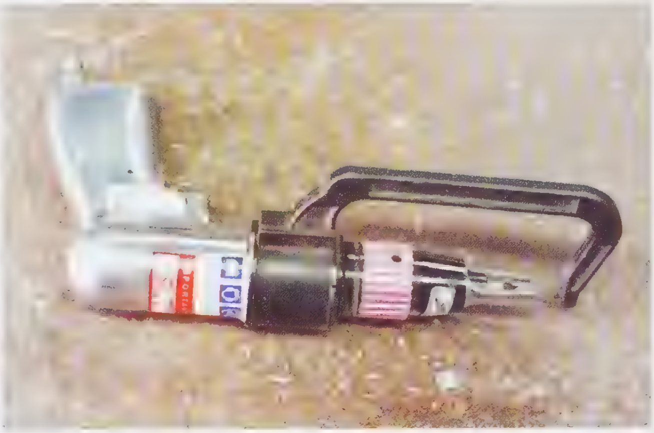


Figure 7-45. *This spot weld cutter tool resembles a drill. This tool is useful for removing spot welds along the edge of a panel.*

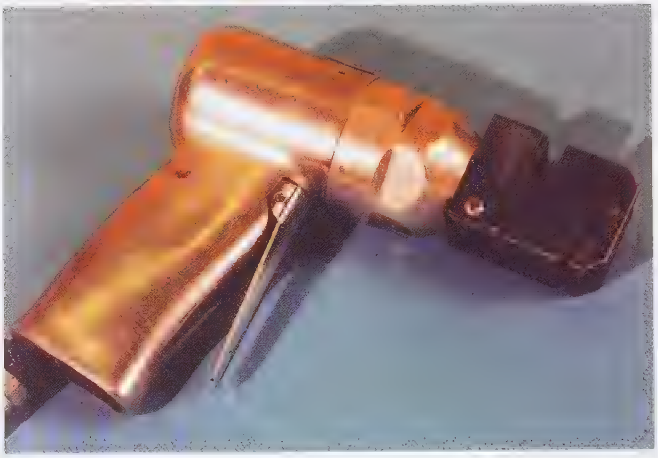


Figure 7-46. *This air-powered combination punch/flanger tool is used to cut holes or create a step edge in a panel.*

NOTE

The air punch/flanger can cut holes along the edge of a panel only. Holes beyond the reach of this tool must be drilled.

Cut-Off Tool

Many different power tools are available to cut metal during panel replacement. **Figure 7-47** shows a ***cut-off tool***. This air tool spins a fiber cut-off wheel, which cuts the metal. The cut-off wheels are available in different thicknesses. Thin wheels wear out quickly when cutting. Thicker wheels last longer and may also be used to dress welds before grinding.

To use a cut-off tool, first scribe a cut line or simply lay out masking tape to indicate a cut line. When viewed from the handle side of the tool, the wheel spins clockwise. The tool is more stable if the cuts are made from left to right. Start at the left edge of the panel. Push the trigger to spin the wheel. Contact the panel and move the tool to the right. This cutting will throw off sparks. The wheels are changed using two wrenches, one to hold the shaft and the other to remove the nut securing the wheel.

Air Chisel

Like the cut-off tool, the ***air chisel*** is used to cut metal. It is often used to make quick, rough cuts on a replacement panel. An air chisel and various bits are shown in **Figure 7-48**. A panel cutter bit should be used to cut sheet metal. The panel cutter bit is easily broken if misused.

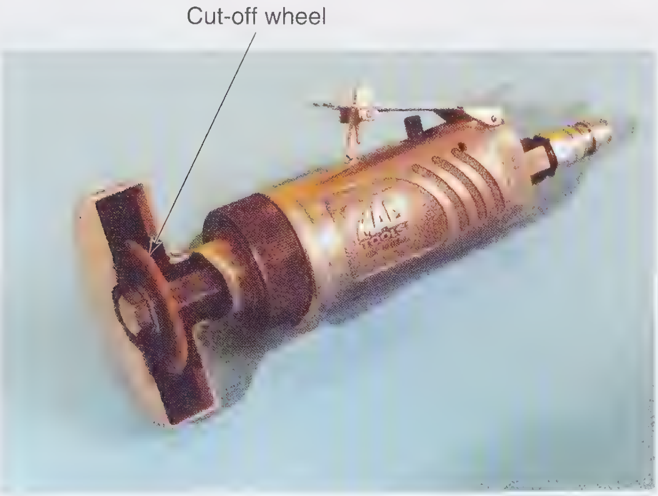


Figure 7-47. *This air-powered cut-off tool can be used to cut through a metal panel.*

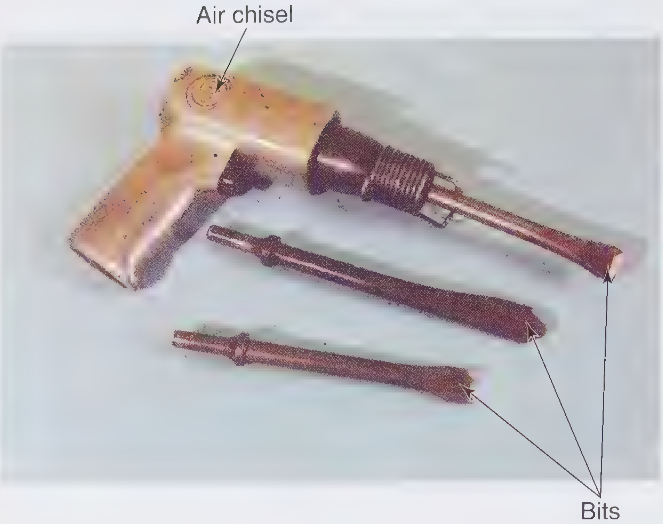


Figure 7-48. *An air chisel can be used to cut metal. Note the different bits that fit the chisel.*

CAUTION

Never use a panel cutter bit to cut through double-folded metal. The double-folded metal may be so hard and thick that it is stronger than the bottom tooth on the bit. Use a cut-off tool to cut double-folded metal.

To use an air chisel, mark the cut line in the same manner as you would when using the cut-off wheel. The panel cutter bit will cut out a 1/8"-wide band of metal. Always consider the width of the bit when planning the cut. Install a bit on the air chisel by unscrewing the retainer spring and removing the keeper. Next, install the bit into the retainer spring and reinsert the keeper. Then, screw the retainer spring into the air chisel. When cutting, start at an edge and follow the cut line. Let the tool do the cutting. Do not force it.

NOTE

It may be difficult to make accurate cuts in high-crown panels when using an air chisel.

Air Saw

An ***air saw*** is simply a power hacksaw. See **Figure 7-49**. When cutting a replacement panel that is not installed on a vehicle, this tool works well. However, when cutting a panel that is installed on a vehicle, adjacent panels may interfere with the movement of the blade. As with other cutters, the blades are easily broken if misused. Always keep the blade perpendicular to the cut. If the blade is bent to the side, it may break.

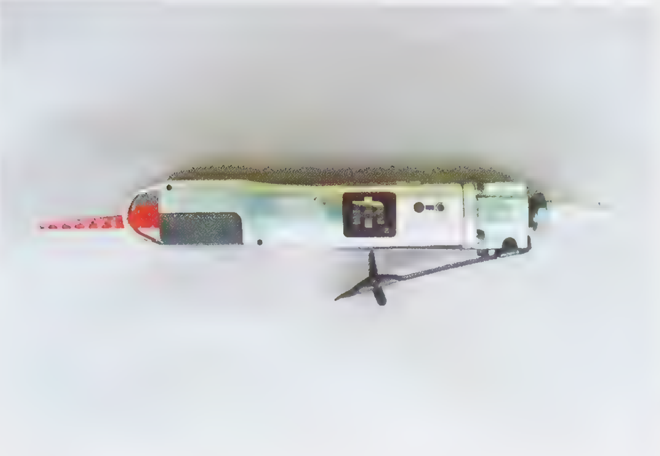


Figure 7-49. *An air saw can be used to cut replacement panels.*

Electric Shears

Electric shears can also be used to cut metal. See **Figure 7-50**. Electric shears are easy to control, and they make precise cuts. They will cut out a 1/8"-wide band of metal, as an air chisel does. Electric shears work best on flat metal. They are not well suited for cutting high-crown panels or flanged areas.

Door Skin Replacement Tool

Replacing a door skin requires a lot of hammer-and-dolly work. Improper use of the dolly can damage the new door skin. The air-powered ***door skin replacement tool***, shown in **Figure 7-51**, takes away much of the hammer-and-dolly labor and minimizes the chances of damaging the new door skin.

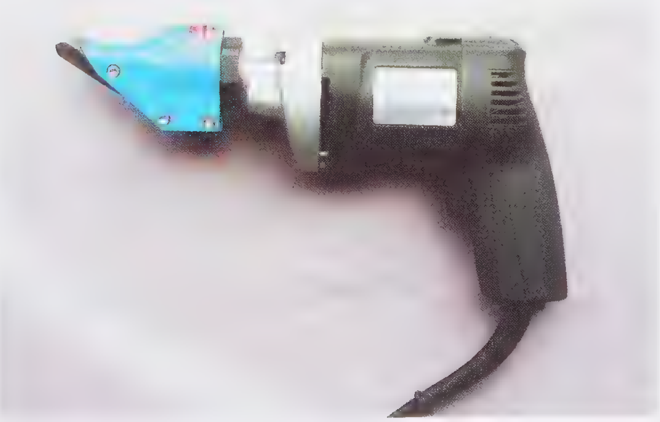


Figure 7-50. *Electric shears can make accurate cuts in flat metal.*

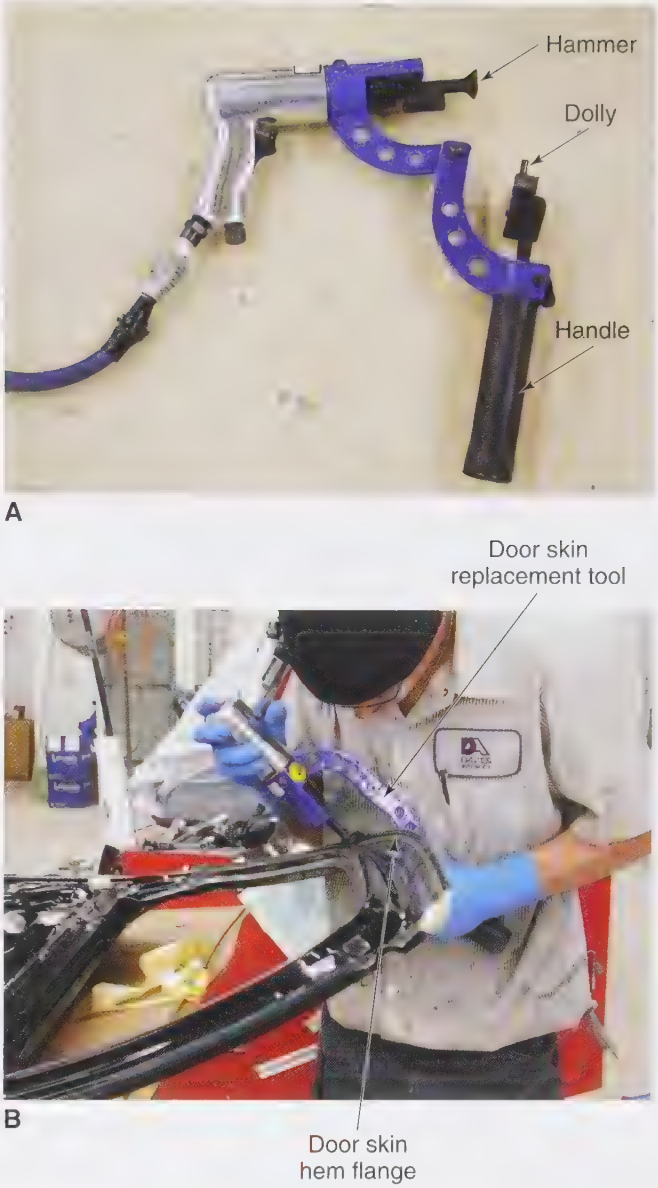


Figure 7-51. *A—This door skin replacement tool hammers the fold in the replacement door skin. B—Door skin replacement tool in use.*

The working area of this tool consists of an air-powered hammer and a hard rubber dolly. In the first step of door skin replacement, the air hammer and rubber dolly are positioned at a 90° angle to each other to fold the door skin hem flange toward the door shell. Once the hem flange is folded, the hammer and dolly are repositioned opposite each other so the hammering action flattens the hem flange. Never hammer on body lines or small radius crowns, as this will cause damage. When used properly, the door skin replacement tool will produce a tight, original-looking hem.

Draw Pin Welder

A ***draw pin welder*** is used when making a one-sided panel repair. A draw pin is welded to bare metal in a low area. A slide hammer, which is attached to the draw pin, is used to raise the low area. **Figure 7-52** shows a typical draw pin welder set. The set consists of the welder, a four-pound slide hammer, and welder tips. The different tips can be used to weld draw pins or rivets, and to shrink stretched areas. **Figure 7-53** shows draw pins welded in place. A T-puller, **Figure 7-54**, is attached to a draw pin and pulled by hand.

A series of pins can be welded to raise a gouge. To set the pins close together, a special attachment is used on the draw pin welder. A gang puller, shown in **Figure 7-55**, can then be used to pull several pins at the same time.

W-shaped wire is shown in **Figure 7-56**. It can also be used to pull a gouge. A draw pin welder with a special tip is used to weld the W-shaped wire to the gouge. A puller is attached to the W-shaped wire to raise the gouge.

To use the draw pin welder, begin by removing the paint from the low area.

NOTE

The welder will not work unless the entire head is in contact with bare metal. Even a small amount of paint will prevent the welder from operating properly. Draw pins cannot be welded to panel edges and some body lines. Only part of the welder head can contact bare metal in these locations.

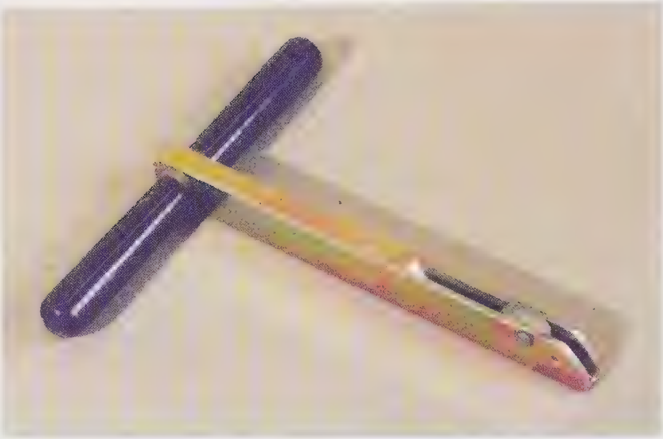


Figure 7-54. *This T-puller is used to raise a single draw pin.*

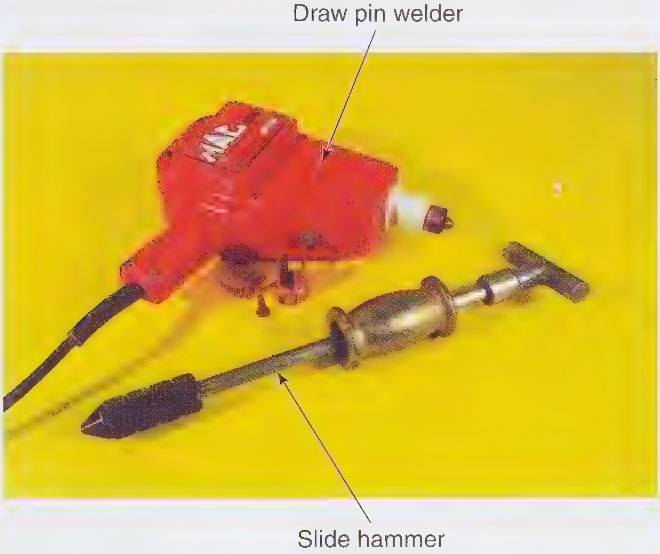


Figure 7-52. *A draw pin welder set consists of the welder, a slide hammer, and various welding tips.*

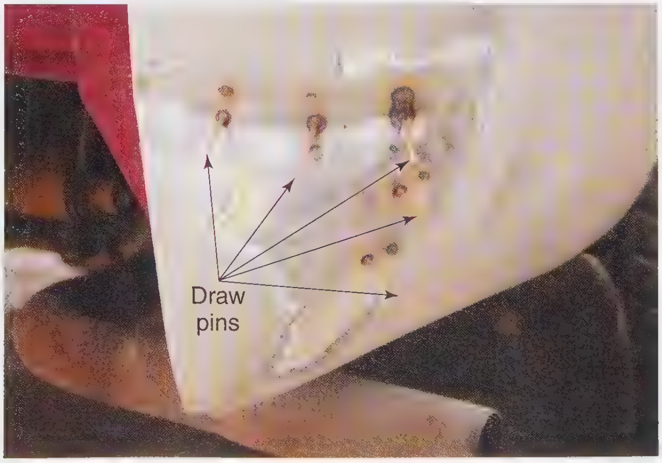


Figure 7-53. *Pulling on these draw pins will raise the low area.*

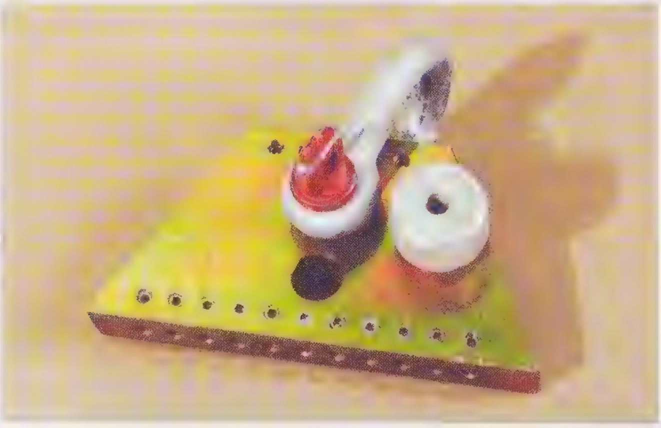


Figure 7-55. *This gang puller is used to raise several draw pins at the same time. The pins fit into the holes on the bottom of the puller.*

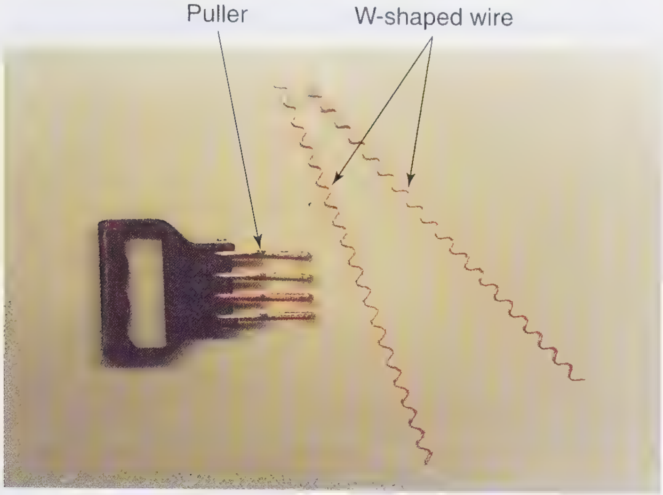


Figure 7-56. *This W-shaped wire is welded into a gouge. The puller is attached to the wire and used to raise the damage.*

Insert a draw pin into the welder's head and position the welder over the damaged area. The welder must be held perpendicular to the damage. Push down on the welder so the entire head is in contact with the bare metal. Push the trigger for one second. Release the trigger and remove the welder. The draw pin should be welded to the panel. To remove the pin, cut the pin's shank off with side cutters and then grind the head from the panel.

The contact area of the welder's head will become contaminated with use. Sand the head with fine sandpaper to keep the contact area shiny. A shiny surface will help ensure good contact with the bare metal.

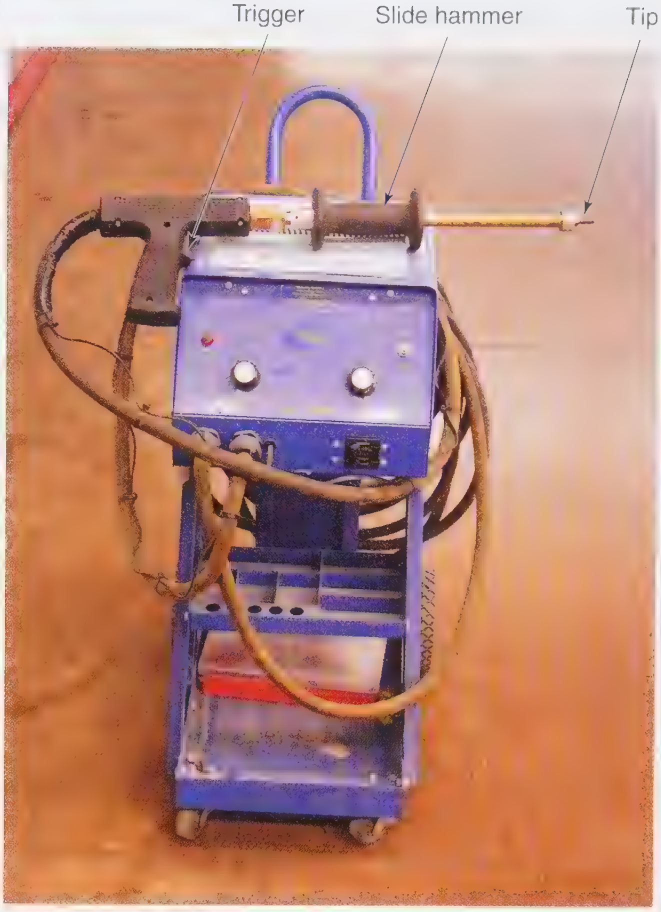


Figure 7-57. *The tip of the rod welder is welded to bare metal in the dent. The welder is then used like a slide hammer to remove the dent.*

Rod Welder

The ***rod welder*** can be used to raise a low spot very quickly. See **Figure 7-57**. Instead of using consumable draw pins, the rod welder simply welds a rod that is attached to a slide hammer to the low area.

To use the rod welder, clean the low area to bare metal. Attach the welder's grounding contact to a bare metal area on the vehicle. Place the welder's rod in the low area and pull the trigger to weld the rod to the panel. Raise the low area by pulling on the rod, slide hammering the rod, or using a leverage bar attached to the rod. After raising the low area, twist the rod to break the weld and release the rod from the panel.

Weld-On Plate

A ***weld-on plate*** can be used to pull a body line or panel edge. One end of the plate is MIG welded to the damaged body line or panel edge. The other end of the plate has a ridge to accept a clamp. The clamp can be pulled with a chain or slide hammer. Different widths of plates are available.

Figure 7-58 shows a weld-on plate in use. The pull force in concentrated on the welds. The plate can also be stitch welded to form a continuous weld. A continuous weld is stronger than spot welds. For a light-duty pull, spot welds are acceptable, as they are easier to make and to remove.

Once the pull has been made, the weld-on plate can be removed by cutting the weld with a cut-off tool. The plate must be cut square after removal. The plate is consumable because it is shortened each time it is welded and cut.

Placement of the plate is important. The plate should not be welded across a buckle. If the plate is welded across a buckle, the buckle cannot move during the pull and additional damage may occur. The buckle must be able to lengthen and move.

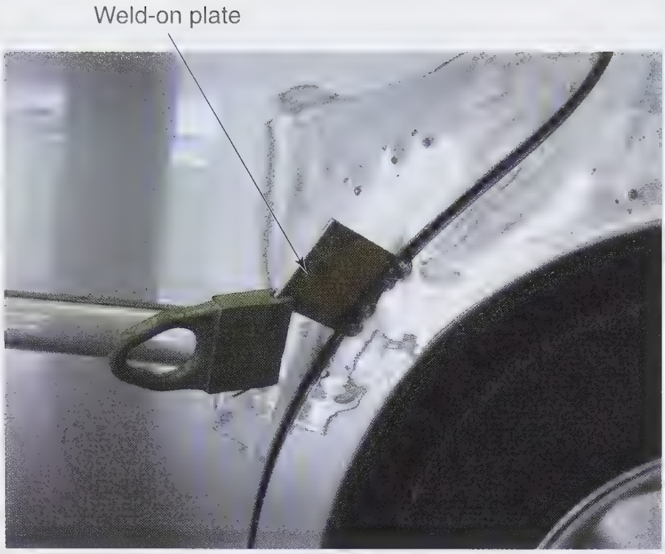


Figure 7-58. *This weld-on plate is attached to a panel edge. The pull is attached to the clamp. The clamp slips over a fold in the weld-on plate.*

Hydraulic Power Set

Low areas can often be pushed out using a ***hydraulic power set***. A four-ton hydraulic power set is adequate for most nonstructural repairs. The set shown in **Figure 7-59** consists of a hydraulic pump, rams, extension tubes, and attachments. To use the power set, connect the hose on the pump to the ram. Turn the valve on the pump clockwise. Pump the handle to force hydraulic fluid from the pump, through the hose, and to the ram. The ram extends from the pressure of the hydraulic fluid. To retract the ram, turn the pump valve counterclockwise. This allows the hydraulic fluid to return to the pump and the ram to retract.

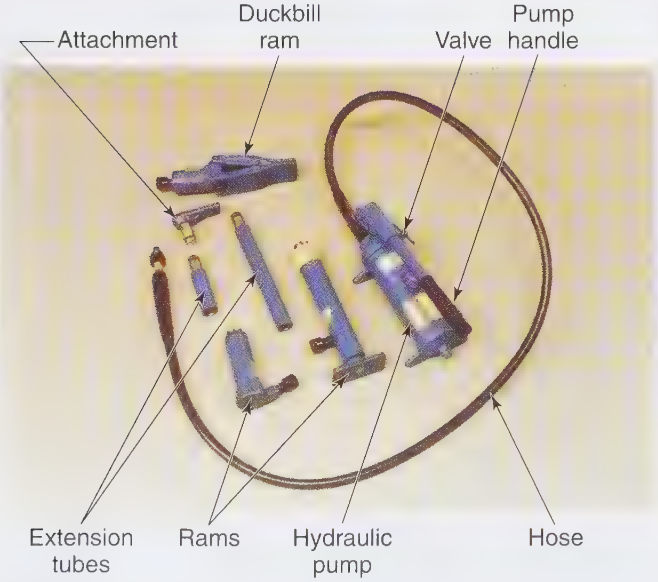


Figure 7-59. *This 4-ton hydraulic power set consists of a hydraulic pump, two straight rams, a duckbill ram, extensions, and an end attachment.*

Rams are available in various sizes. A small, or short, ram is useful in confined areas, such as inside a crushed door. A large ram can be used where a lack of space is not a problem, such as inside a trunk.

A duckbill ram has two jaws. One jaw is stationary, and the other jaw moves under hydraulic pressure. The duckbill can be inserted inside a very narrow area, such as a damaged quarter panel.

All rams require a solid, immovable base. If the base is weaker than the damage, the base will be damaged when pressure is applied to the damage. The ram should have a foot installed.

The ram has a finite amount of extension. Once the maximum extension is reached, the ram will not increase in length. If this occurs, stop pumping, release the pressure, and allow the ram to retract. Then install an extension tube and begin pumping again. The extension tubes should not be placed between the base and the ram. Instead, they are used between the ram and the damage. Attachments are used on the end of the extension tube at the damage. A narrow attachment will concentrate the force in a small area. A wide attachment will spread the force out over a larger area. An L-shaped attachment will offset the force. Blocks of wood may be placed at the base or at the attachments to spread the force over an even larger area.

To maintain the hydraulic power set, check the hydraulic oil level in the pump. Add hydraulic jack oil as needed. Keep the connectors clean. Dirt or grit on the connectors can get into the ram, damaging its internal seals. Keep the ends of the extension tubes clean. Dirty ends will cause binding when the ram retracts. Keep the pump and hose in a case when not in use. The hose can be damaged if something is dropped on it.

Nonstructural Repair Materials

This section explains commonly used nonstructural repair materials. These materials include fillers for steel and aluminum repair, as well as sandpaper and adhesives.

Body Fillers

Body fillers are used to fill shallow dents in panels that cannot be removed by straightening techniques. See **Figure 7-60**. All body fillers are made from polyester resin. Polyester resin is a thick liquid that changes to a

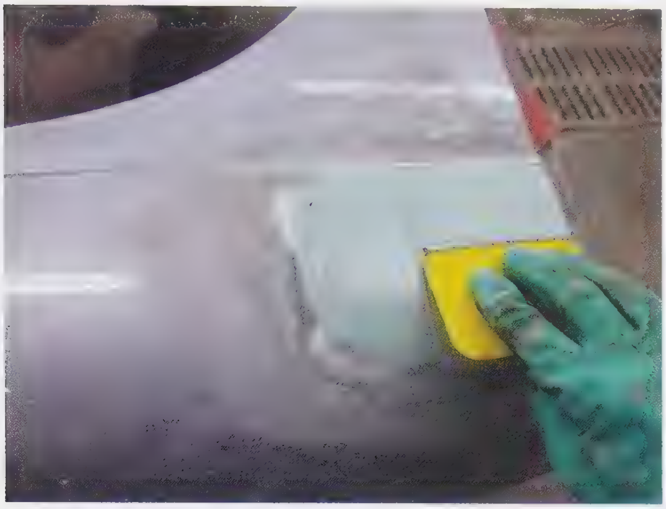


Figure 7-60. *After straightening, body filler is added to the low area.*

solid when mixed with a ***catalyst***, or hardener. Cured polyester resin is very hard. Bulking agents are components in filler that make cured filler easier to sand. The type of bulking agent used determines the type of filler. There are several types of fillers available.

Lightweight filler contains glass beads and a small amount of talc as bulking agents. It is catalyzed with paste hardener and cures solid, but it can be easily sanded. This type of filler is used to fill low areas.

NOTE

Lightweight body filler is sometimes used to fill holes in panels. Generally, this is not recommended because lightweight filler is not waterproof. Moisture traveling through the cured filler can cause the repaired panel to rust.

Fiberglass-filled filler uses either short or long strands of fiberglass as a bulking agent. The fiberglass strands help make this filler strong. Fiberglass-filled filler contains a higher proportion of polyester resin than lightweight filler. Therefore, it cures hard when catalyzed. The large percentage of polyester resin also makes this filler waterproof. Therefore, it can be used to fill rust holes. Liquid hardener is the catalyst.

Aluminum-filled filler has aluminum powder as a bulking agent. It, too, is waterproof and contains a greater proportion of polyester resin than lightweight filler. Therefore, it cures hard when catalyzed with liquid hardener. This filler type can also be used to fill rust holes.

Heavyweight filler contains talc as a bulking agent. It is catalyzed with a paste hardener and sands coarse. Heavyweight filler can be used to fill low spots.

Premium filler contains fine glass beads as a bulking agent. This type of filler can be applied over sanded paint and adheres readily. It is catalyzed with a paste hardener and sands to a smooth finish. Premium filler is recommended for filling low areas.

Putty is a type of filler that contains fine glass beads as the bulking agent. It is catalyzed with a paste hardener and sands to a smooth finish. Putty is used to fill scratches or pinholes in cured filler, or as a final coat over cured lightweight filler. Glaze is also a type of filler. Extremely fine glass beads are used as a bulking agent in this material. Glaze is catalyzed with a paste hardener and sands smooth. It is used to fill scratches in primer-surfacer areas.

WORKING SMART

A new type of filler uses *UV light* rather than hardener to catalyze the cure. The UV light source can be the sun or a 400-watt UV lamp. This type of filler helps eliminate the problems associated with adding the incorrect amount of hardener to the filler.

When choosing filler, it is important to consider the material's properties. In most cases, these properties are listed on the filler's container. Common properties include:

- Tack-free— Tack-free filler produces a hard surface. Some fillers, such as heavyweight fillers, do not cure hard on the surface. Instead, the surface remains tacky or gummy. The tacky surface is removed with a file before sanding.
- Stain-free—Excessive hardener added to the filler can be pulled from the cured filler by evaporating paint solvents, causing discoloration of the base coat. The discoloration is called staining. Stain-free filler resists paint solvents.
- Non-bleeding—Photo-reactive chemicals in the filler and hardener are pulled through the primer and basecoat by solvents in the clearcoat, causing a yellow discoloration that may appear months after the repair. Non-bleeding filler uses a polyester resin that resists the solvents in the clearcoat.

Sandpaper

Sandpaper is used in nonstructural repair to remove paint and sand filler. Sandpaper is rated by abrasive grit size. A number representing the abrasive grit size is printed on the back of the sandpaper. See **Figure 7-61**. The smaller the number, the coarser the abrasive. A 24-grit disk and a 180-grit sandpaper are shown in **Figure 7-62**. Notice how much bigger the abrasive grit is on the 24-grit disk than on the 180-grit paper. The 24-grit disk will sand much faster than the 180-grit sandpaper, but it will leave the surface much rougher.

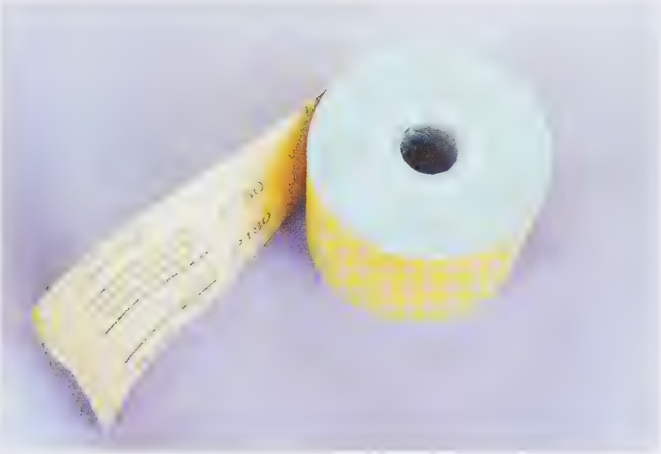


Figure 7-61. *The grit number is printed on the back of the sandpaper. This is 180-grit sandpaper.*

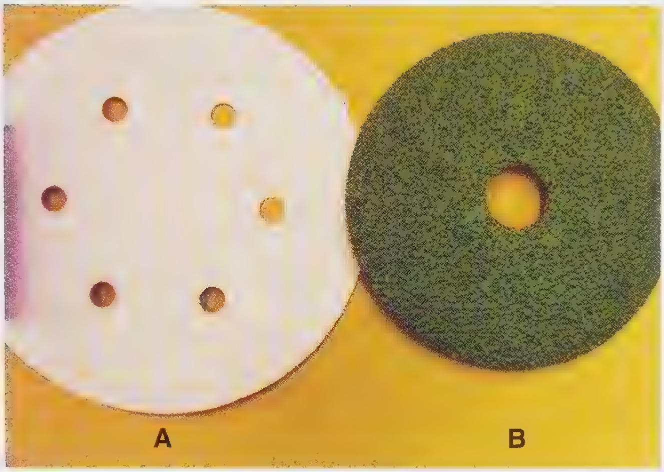


Figure 7-62. *Compare these two sanding disks. A—A 180-grit disk. B—A 24-grit disk.*

A coarse abrasive is used to rapidly remove paint or filler at the beginning of a repair. A finer abrasive will not remove material as quickly, but it will leave the surface smooth. A fine abrasive is used to finish the repair. Regardless of the grit size, the abrasive will gradually wear down with use. Once the abrasive is smooth and no longer sharp to the touch, the sandpaper should be replaced. Common sandpaper grit sizes and their applications are given in **Figure 7-63**.

In addition to abrasive grit, sandpapers are classified as either open-coat sandpaper or closed-coat sandpaper. Open-coat sandpaper has spaces between the abrasive particles. These spaces allow the sanded material to accumulate between the abrasive particles. Closed-coat sandpaper does not have spaces between the abrasive particles. This type of sandpaper will clog rapidly. Therefore, closed-coat sandpaper is used in finish applications where only small amounts of material are removed.

Sandpaper Used in Panel Repair

Grit Number	Form	Application
24	Disk	Aggressive paint, weld, and metal removal
36	Disk	Paint and metal removal
40	Sheet	First sand of body filler
80	Sheet	Second sand of body filler
80	Disk	Less aggressive paint removal
180	Sheet	Final sand body filler

Figure 7-63. *This chart lists the applications for the various grits of sandpaper used in the collision repair shop.*

When large amounts of material are removed while sanding with a coarse abrasive, the sandpaper will become clogged with the sanded material. Clogged sandpaper cannot effectively remove material. To remove clogging, hit the sandpaper with a wire hoop, such as the one shown in **Figure 7-64**.

Sandpaper is available in disk and sheet form. Disks designed for use on a grinder may have a fiber backing. Fiber-backed discs are available in 24-, 36-, and 50-grit varieties. Disks can also have a paper backing. Both 80- and 180-grit paper-backed disks are used for panel repair. Paper-backed disks may have an adhesive surface or a Velcro surface. The adhesive-backed discs are designed to stick to a smooth pad on a dual-action sander. The Velcro-backed discs are designed to adhere to a Velcro pad on the sander. An advantage

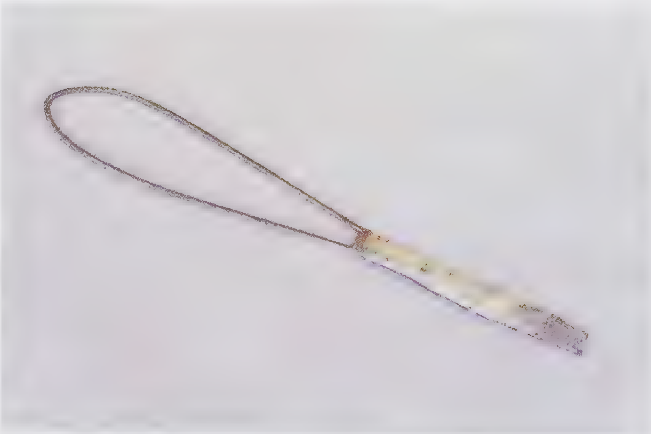


Figure 7-64. *This wire loop can be used to slap the sandpaper to remove contamination.*

to a Velcro-backed disk is that it can be reused. Once an adhesive-backed disk is removed, it cannot be reinstalled. If it were, it would not stick adequately to the pad and would fly off as the dual-action sander rotates.

Sheets of sandpaper can have a thick or thin paper backing, depending on the abrasive grit size. Coarse sandpaper, such as 36- or 40-grit, has a thick paper backing. Finer sandpapers, such as 80- or 180-grit, have a thinner paper backing. Sheets cut for a long board are 2 3/4" (7 cm) wide and 17 1/2" (44 cm) long. The sheets may be adhesive backed, Velcro backed, or untreated. Sandpaper is also available in rolls that can be cut to any length.

If possible, the sandpaper should span the filler. This will allow the edges of the sandpaper to rest on undamaged metal. This is not possible if the filled area is more than 17" (43 cm) wide.

Adhesives

Adhesives are used to glue some replacement steel panels in place. Not all panels can be replaced using adhesives. Structural parts must be welded during replacement. In some cases, both adhesives and welds are required to secure a panel. Panels that are commonly glued in place include door skins, bed sides, and patch panels. **Figure 7-65** shows adhesive added to a door frame during door skin replacement. Check the manufacturer's instructions to see if a replacement panel can be glued rather than welded.

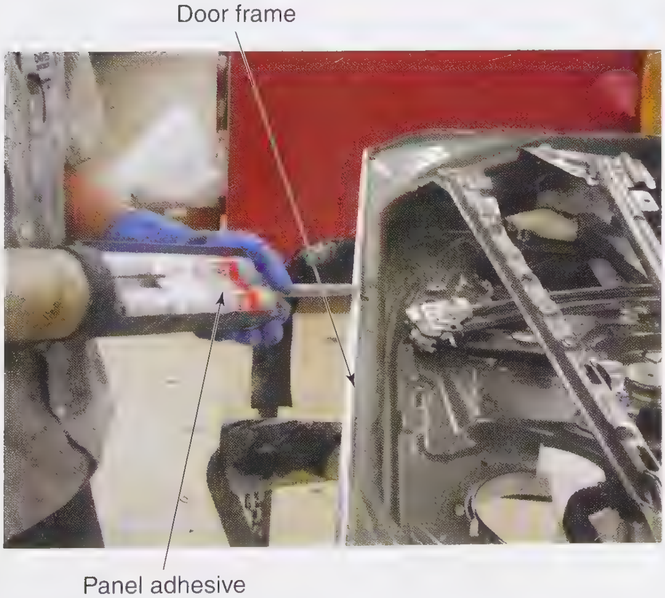


Figure 7-65. *Panel adhesive will bond the replacement door skin in place.*

The major advantage of adhesives is that they do not burn off the corrosion protection the way welding does. Additionally, there is no chance of warping the panel, and the adhesive forms a waterproof seal.

CAUTION

Different adhesive manufacturers may have slightly different application recommendations. The wrong application method may lead to joint failure. Refer to the product manufacturer's literature for specific instructions.

Before applying adhesive, carefully test fit the replacement part. Make sure both mating surfaces have been cleaned to bare metal. Apply a bead of adhesive to one of the mating surfaces and install the replacement panel.

Once the replacement panel is installed and the adhesive contacts both mating surfaces, the panels should not be separated. If the replacement panel is not in alignment, it can be shifted slightly without pulling the adhesive free. The replacement panel must be clamped in place. Clamping is necessary to form a strong bond. The adhesive may take several hours to cure. Do not remove the clamps until the curing is complete.

Summary

- Body repair hand tools are used to reshape damaged or misaligned sheet metal, to apply body filler, and to sand cured filler to the proper contour.
- Body hammers are used to move damaged sheet metal back to its original contour. These hammers have two working surfaces.
- Dollies can be used to support the underside of a panel when tapping on the outside. They can also be used to hit the damage either directly or indirectly.
- A spoon is used to spread out the force of a hammer blow.
- Pry picks are designed to be inserted inside a panel to raise low spots.
- The slide hammer is useful for adjusting panels and raising damage.
- The friction jack consists of an L-shaped rod and a jack head. As the friction jack's handle is pumped, the jack head moves along the rod.
- The wide face of a body chisel is used to raise a damaged body line.
- Metal files are used to identify high and low areas in a panel.
- Filler tools are used to apply and level body filler.
- A cable-tensioning device attached to a strong base can be used to lengthen a panel.

- A grinder spins a coarse abrasive disk at a high speed to remove metal and paint.
- An air file is used to sand filler. There are two basic types of air files: straight-line air files and orbital air files.
- The orbital sander spins a coarse disk at a high speed. This tool will rapidly sand filler.
- Spot weld cutters are used to drill out spot welds, a very common task in welded panel replacement.
- The air-powered door skin replacement tool minimizes the chances of damaging the new door skin.
- A draw pin welder is used when making a one-sided repair. A draw pin is welded to bare metal in a low area. A slide hammer, which is attached to the draw pin, is used to raise the low area.
- Instead of using consumable draw pins, the rod welder simply welds a rod attached to a slide hammer to the low area.
- A weld-on plate can be used to pull a body line or panel edge.
- Low areas can often be pushed out using a hydraulic power set. A four-ton hydraulic power set is adequate for most nonstructural repairs.
- Body fillers are used to fill shallow dents in panels that cannot be removed by straightening techniques.
- Sandpaper is used in nonstructural repair to remove paint and sand filler. Sandpaper is rated by abrasive grit size.
- Adhesives are used to glue some replacement steel panels in place.

Review Questions

Please do not write in this textbook. Place your answers on a separate sheet of paper.

1. A flat-faced hammer is also called a(n) ______ hammer.
2. A(n) ______-faced hammer can be used to straighten any area except a body line.
3. What type of hammer gathers the metal together when it strikes the panel?
4. Using a body hammer is the same as using a carpenter's hammer to drive a nail. True or False?
5. To decrease the force of the hammer blow, hold the handle in the ______ position.
6. A(n) ______ dolly has serrations.
7. The dolly should match the ______ of the undamaged panel.
8. A pry pick is inserted inside a panel to raise low spots. True or False?
9. Explain how to use a metal file.
10. Plastic filler should be mixed on a(n) ______ surface.
11. For finish sanding, a long board with 40-grit sandpaper should be used. True or False?
12. Explain how to install sandpaper on a sanding block.
13. On a high-crown surface, a sanding stick should be kept flat. True or False?
14. Explain how to drill out a spot weld with a hole-type spot weld cutter bit.
15. A draw pin welder is used to set draw pins on bare metal. True or False?
16. Extension tubes should be placed in between the ram and the ______.
17. All body fillers are made from ______ resin.
18. Which removes paint faster, 80-grit sandpaper or 24-grit sandpaper?
19. When sanding filler, the sandpaper should ______ the filler.
20. List two advantages of using adhesive rather than welding.

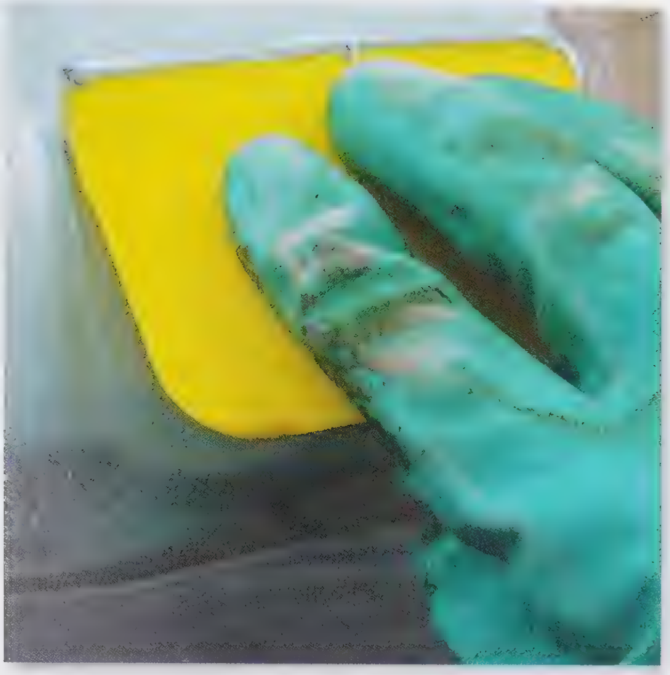
ASE-Type Questions

1. Technician A says that a sharp pick hammer moves a small area. Technician B says that a blunt pick hammer will likely pierce the metal. Who is right?
   (A) A only.
   (B) B only.
   (C) Both A and B.
   (D) Neither A nor B.
2. Which of the following tools is used to remove a spring from a door with welded-on hinges?
   (A) Screwdriver.
   (B) Locking pliers.
   (C) Spring compressor.
   (D) Upholstery tool.
3. A metal file should contact the metal ______.
   (A) as the file is pushed away from the operator
   (B) as the file is pulled toward the operator
   (C) when pushing away and pulling toward the operator
   (D) None of the above. Metal filler should never contact the metal.
4. Technician A mixes filler and hardener on a piece of cardboard. Technician B says that mixed filler is applied with a spreader. Who is right?
   (A) A only.
   (B) B only.
   (C) Both A and B.
   (D) Neither A nor B.

5. Technician A says that the buffing technique with a grinder removes metal. Technician B says that any type of grinding produces heat. Who is right?
   (A) A only.
   (B) B only.
   (C) Both A and B.
   (D) Neither A nor B.
6. Technician A says that an air punch makes holes only at the edges of a panel. Technician B says that no pilot hole is required when drilling out a spot weld with a hole saw. Who is right?
   (A) A only.
   (B) B only.
   (C) Both A and B.
   (D) Neither A nor B.
7. Technician A wants to cut double-folded metal with an air chisel. Technician B wants to use a cut-off wheel to cut double-folded metal. Who is right?
   (A) A only.
   (B) B only.
   (C) Both A and B.
   (D) Neither A nor B.
8. Which of the following requires a liquid hardener?
   (A) Aluminum-filled filler.
   (B) Putty.
   (C) Glaze.
   (D) Premium filler.
9. Technician A says lightweight filler should be used to fill rust holes in panels. Technician B says fiberglass-filled filler should be used to fill rust holes in panels. Who is right?
   (A) A only.
   (B) B only.
   (C) Both A and B.
   (D) Neither A nor B.
10. Which of the following may be applied to fill pin holes?
   (A) Aluminum-filled filler.
   (B) Fiberglass-filled filler.
   (C) Putty.
   (D) Heavyweight filler.
11. Which of the following properties of filler prevents discoloration by photo-reactive chemicals?
   (A) Color safe.
   (B) Tack free.
   (C) Stain free.
   (D) Non-bleeding.
12. Technician A says that the abrasive grit number is printed on the back of the sandpaper. Technician B says that grinding disks have a paper backing. Who is right?
   (A) A only.
   (B) B only.
   (C) Both A and B.
   (D) Neither A nor B.
13. What grit of sandpaper is used to final sand filler?
   (A) 24.
   (B) 36.
   (C) 40.
   (D) 180.
14. Which of the following should be used to sand a 10"-wide patch of filler?
   (A) A 7" orbital sander.
   (B) A 5" sanding stick.
   (C) A 9" sanding block.
   (D) A 12" long board.
15. Misalignment occurs when gluing a replacement door skin to a door frame. Technician A says to carefully lift the door skin away from the door and move the skin to the proper location. Technician B says to slightly shift the door skin but not to separate it from the door frame after the panels have been glued together. Who is right?
   (A) A only.
   (B) B only.
   (C) Both A and B.
   (D) Neither A nor B.

EXPLORER
Ford

This late-model sport-utility vehicle is equipped with a lightweight aluminum hood. Special precautions must be taken when repairing aluminum body panels. (Ford)



Chapter 8

Nonstructural Panel Repair

Objectives

After studying this chapter, you will be able to:

- Describe the individual steps in the nonstructural panel repair process.
- Explain how to rough out specific types of nonstructural damage.
- Demonstrate the metal finishing process.
- Use body filler to restore panel contour.
- Describe the considerations that must be taken into account when repairing aluminum panels.

Technical Terms

attachment
blind picking
bull's-eye pick
chasing the dent
displaced metal
double fold
false stretch
filing
high spot
hookup
kinking
leveling
lift reaction
low spot
mechanical adhesion
metal finishing
one-sided repair
picking
raising
shock force
shrink fence
shrinking
stretch
stretching
tension
two-sided repair
upset
warp damage

Introduction

This chapter explains how to straighten damaged sheet metal. It begins by discussing the skills needed to perform basic straightening operations. It then describes the basic nonstructural repair operations: analyzing damage, planning the repair, accessing the damage, roughing out, and finishing. These operations are then combined in a section on repairing specific types of nonstructural damage.

Fundamentals of Damage Repair

In this section, an empty soda can will be used to demonstrate the damage repair process. The side of the can is a high-crown surface. Lateral force on a high-crown surface will cause arrowheads. Press on the side of the can with your thumb to make arrowheads. Look closely at the damage. The arrowheads point away from each other. The metal between the arrowheads is flat, and the flattening extends out to both ends of the can. This flattened area is ***displaced metal***, which is undamaged but held out of position by the arrowhead buckles. To correct the damage, pinch the arrowheads as shown in **Figure 8-1**. The buckles at the arrowheads will be released, and the can will pop back to its normal shape.

Next, damage the can severely by pressing one side in so far that it touches the opposite side. Notice how the ends of the can move toward each other as the crown collapses. To straighten this damage, first pull the ends away from each other. This will begin to restore the length, and the flattened metal will begin to rise. Pinch the buckles out as you pull on the ends of the can. The metal may tear from metal fatigue, but the approximate shape will be restored by pulling on the ends and pinching the buckles.

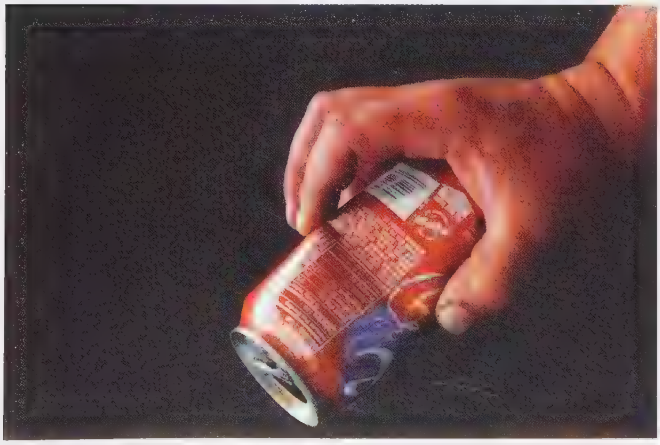


Figure 8-1. *Pinching the arrowheads on this soda can will release the buckles.*

Of course, vehicle panels are not made of thin aluminum and generally do not have a high crown like the soda can, but you can learn about vehicle repair from this type of demonstration. Buckles hold damage in place. If the buckles are released, the displaced metal will return to its proper position. Also, if a change in length is present, length must be restored as the buckles are released. You would not be able to straighten the severely damaged can if you did not restore the length as you released the buckles. Keep these simple can demonstrations in mind as you read the rest of this chapter.

Chapter 4, *Fundamentals of Collision Damage*, explained that there are only two ways a panel can be damaged, longitudinally and laterally. Longitudinal force causes folds or simple hinge buckles in an immobile flat panel. Overall panel length is reduced. In an immobile panel with body lines, a longitudinal force causes collapsed hinge buckles, again reducing overall length. Lateral force on a flat panel first moves the ends of the panel closer together. It then stretches the metal, increasing the surface area.

On a high-crown panel, lateral force causes arrowheads. In an arrowhead, the crown is flattened and the surface area is reduced.

All buckles are the result of grain rearrangement. The grains in the metal are too small to be seen, but their arrangement determines the shape of the metal. A force greater than the yield point will rearrange the grain set, causing buckles and changing the shape of the panel. A ***stretch***, or an increase in surface area, means that the grains have been thinned, flattened, and elongated. An ***upset***, or a reduction in surface area, means that the grains have been shortened, thickened, and bunched together. A stretched area is repaired by shrinking the surface area. An upset area is repaired by stretching the surface area.

Nonstructural Panel Repair Steps

The following section outlines the individual steps in the nonstructural panel repair process. A combination of these operations is used to complete most nonstructural panel repairs. The entire repair sequence involves reading the estimate, analyzing the damage, planning the repair, accessing the damage, roughing out, and finishing.

Reading the Estimate

The first step in any repair is to read the estimate or repair order. Study each line of the estimate. Find out which parts will be repaired and which parts must be replaced.

Analyzing Damage

The next step in the repair process is to analyze the damage. The collision repair technician must be able to identify high and low spots in a panel. Beginners can feel that a panel has ripples, but they often cannot determine if a particular spot is a ***high spot*** (above level) or a ***low spot*** (below level).

The first way to develop this skill is to carefully examine the panel by sight. If the panel has paint on it, examine the panel inside the shop, out of direct sunlight. Sight the overhead light reflection in the painted surface. If there is a bend in the reflection, there is a dent in the panel. Study the damage carefully.

Next feel for damage. Use your entire hand as shown in **Figure 8-2**. Extend your arm and slowly drag your hand toward your body. It is important to use your entire hand and not just your fingers. Feeling with just your fingers will not reveal all the damage. A shop towel placed between your hand and the panel will reduce friction and make irregularities easier to feel. A towel must be used to find dents on a bare metal panel, as the bare metal produces a great deal of friction.

On a panel that is crowned in only one direction, a straightedge can be used to identify highs and lows. **Figure 8-3** shows a straightedge being used on a door. The door is crowned from top to bottom. The straightedge is held perpendicular to the crown. If the straightedge rocks on a point, the point is a high spot. Low spots will be seen as gaps between the straightedge and the panel.

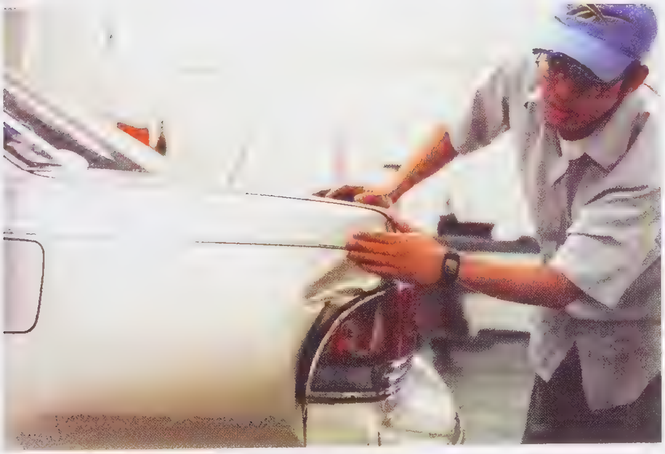


Figure 8-2. *This technician is using his hand to identify high and low spots. Always use your entire hand when feeling for damage.*

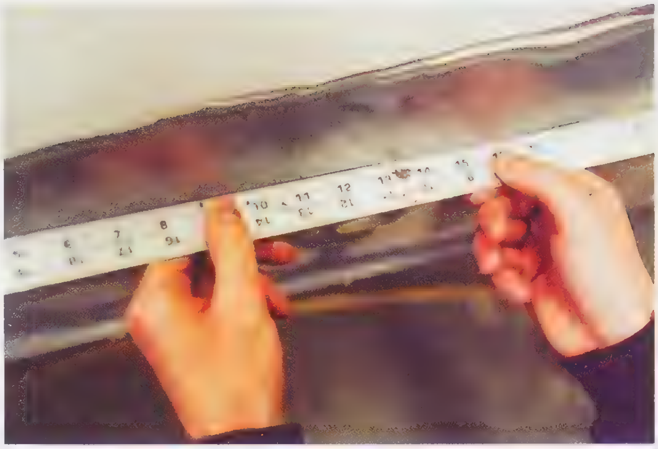


Figure 8-3. *A straightedge can be used to identify highs and lows in a panel. Note that a low spot is visible near the 12 1/2" mark.*

Once high and low spots have been identified with a straightedge, go back and feel them. Note the difference in feel between a high spot and a low spot. A straightedge cannot be used on a double-crown panel (a panel crowned from left to right and from top to bottom). On this type of panel, you must rely on your ability to feel the highs and lows.

As you check the panel for the high and low spots, identify all the buckles. When studying the damage, think through the collision event and ask yourself the following questions:

- Are body lines involved?
- What types of buckles are found?
- Are buckles consistent with the force direction?
- Has the overall length of the panel changed?
- Has the surface area changed?
- Did longitudinal force cause folding?
- Did lateral force cause stretching or arrowheads?
- Are internal braces or inner panels damaged?
- What part of the damage is the strongest?

By answering these questions, you will have forced yourself to look closely at the damage. A careful analysis of the damage is essential to making a proper and quick repair.

Only after you carefully examine and analyze the damage will you be able to decide if the damaged part should be repaired or replaced. One way to determine this is to compare the cost of repair to the cost of replacement. If the cost of repair is more than 75% of the replacement cost, the damaged part is generally replaced. For example, the estimated time required to repair a dented fender is 4 hours. At the shop labor rate of $50 per hour, the cost of repair would be $200. The cost of a replacement fender is $150, plus 2 hours labor to install the fender. The total cost of replacement is $250. The repair cost is more than 75% of the replacement cost, so in this example, the fender would be replaced rather than repaired.

Easily replaced, low-cost panels, such as fenders and door skins, are often replaced if they have more than minor damage. A quarter panel, which is relatively expensive and time-consuming to replace, will generally be repaired even when moderately damaged.

Another consideration when determining whether a panel should be repaired or replaced is the ease of repair. The ease of repair is directly related to the cost of repair. Low-crown panels, such as hoods and roofs, may be replaced rather than repaired if they are damaged. Repairing a damaged low-crown panel would be difficult and time-consuming. This is especially true if the hood is aluminum. A low-crown panel is more difficult to repair than a high-crown panel.

Figure 8-4 shows a damaged quarter panel. The metal is torn and there is no access to the back of the panel. Alignment of the torn edges would not be possible. Therefore, the panel should be replaced.

Longitudinal force on a body line may cause two or more buckles to form at a pivot point, such as an internal brace. These buckles, which are referred to as a ***double fold***, are close together. The metal in the double fold is work hardened, both by the panel forming process and by the damage resulting in buckles. When sheet metal is severely damaged in this way, the folds are so hard that straightening would be difficult. Heat could be applied to the folds while pulling, but the customer would be better served by replacing the panel.

Similarly, internal brace damage is generally not repaired. **Figure 8-5** shows a damaged hood. The internal hood braces are bent, and there are double folds in the metal at the edge of the hood. Because the brace is attached to the hood skin, the inside of the brace is not accessible. Repair is not practical, and the hood should be replaced.

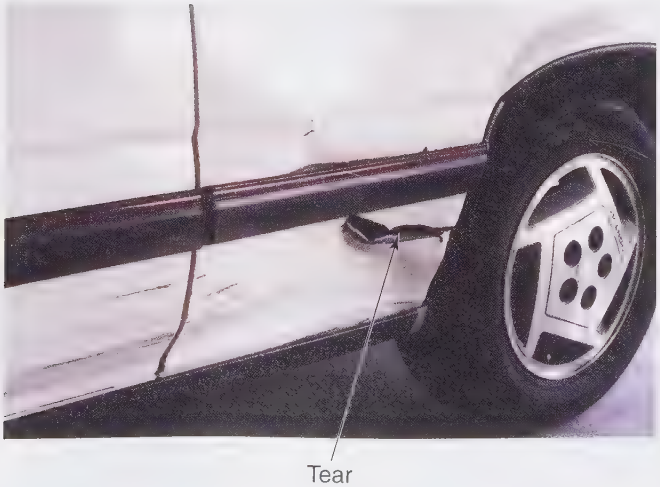


Figure 8-4. *This quarter panel was torn open during a collision. The panel is not repairable.*

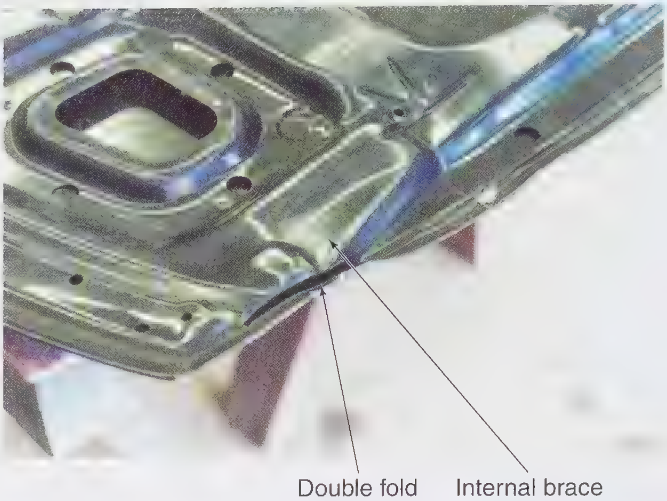


Figure 8-5. *The internal structure of this hood was damaged during a collision with another vehicle. Therefore, the hood should be replaced.*

Planning the Repair

Planning involves thinking through each step in the repair process. Think of a plan as a road map. Can you reach a destination without a map? Maybe, but you could end up backtracking. A technician who can analyze and plan will prevent wasteful backtracking when making repairs.

To repair panel damage caused by longitudinal force, the panel's length must be restored. To repair damage caused by lateral force, not only must the length be restored but the surface area may also have to be changed. In both situations, buckles must be released. In most types of damage, the panel length should be restored first, and then the buckles can be released.

Your ability to plan will increase with experience. Always take the time to devise a plan before starting a repair. As you develop your plan, you must:

- Identify obstructions to be removed (emblems, moldings, handles, etc.).
- Determine if access to the back side of a panel is necessary and, if so, decide how to access the back side of the damage.
- Determine what tools are needed to make the repair.
- Determine the sequence of basic operations.
- Make sure the shop equipment required for the repair will be available when needed.

- Determine if an assistant is required to make the needed repairs.
- Make sure all the required materials are on hand (sandpaper, filler, etc.).
- Decide which buckles will be worked first.
- Identify the area that will be filled.
- Determine how long the repair will take.

Accessing Damage

Before you can begin the repair of a damaged panel, various components, such as moldings and trim panels, must be removed from the vehicle to allow access to the damage. Look closely at the part to be removed. This will generally give you clues as to how the part is attached. Always think about how a part was installed. Work carefully when removing parts. Plastic parts are easily damaged if handled improperly.

Body side molding can be bolted, clipped, or glued in place. For bolted moldings, simply access the back side of the panel and remove the bolts. To remove clip-on chrome moldings, push up on the bottom of the moldings. This will release the clip at the top of the molding. Then pull the top outward to remove the molding. Remove the clips from the welded-on studs by tapping the clips sideways. See **Figure 8-6.**

Glued-on plastic moldings can be removed with a special attachment on an air chisel. The flat attachment cuts the glue between the molding and the vehicle. Another way to remove glued-on moldings is to heat a putty knife and use the hot edge of the knife to cut the glue. The putty knife can be heated with a propane torch. Make sure the putty knife's edge is straight. A ragged knife edge may cut into the molding or the vehicle. Be very careful when cutting metal-backed or metal-containing moldings. If the molding is undamaged and is intended to be reused, bending the molding will ruin it. If the molding is metal backed and the metal backing is damaged, carefully grind off the metal from the back side of the molding. This will allow the molding to straighten. Plastic moldings may curl up after removal. To solve this problem, put the molding outside in the sun to heat it. This will help restore its shape.

Metal wheel opening moldings are screwed into the wheel openings. Rust often locks the screws tightly in their holes. To make removal easier, use an air chisel to vibrate the screws before attempting to remove them. See **Figure 8-7**. Do not use the chisel to cut off the screws; just make them vibrate. The vibration will free the screws, allowing them to be removed easily.

For access to the back side of a fender, the fender liner can be removed. In most cases, these plastic liners are held in place with plastic rivets or bolts. **Figure 8-8** shows how to remove a plastic rivet. Bolts are removed with a socket and ratchet. The wheel may have to be turned to access all the fasteners. On some vehicles, the back side of a fender can be accessed by removing the headlight assembly. See **Figure 8-9**.

Some hoods have insulated pads that must be removed to access damage. These pads are held in place with clips. Use a clip tool as shown in **Figure 8-10** to remove the clip. After the clip is removed, the pad can be easily removed from the hood.

Doors can be quite frustrating to take apart. The door trim panel can be difficult to remove. Screws may be hidden behind caps that must be removed to access

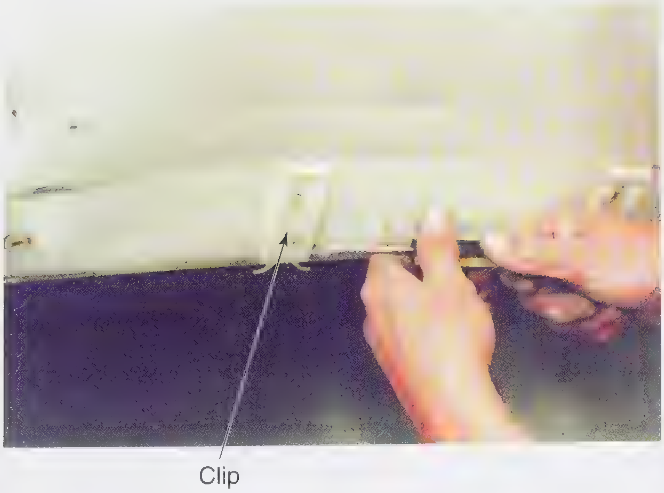


Figure 8-6. *The molding has been removed from this clip. Pushing up on the molding released the molding from the clip. To remove the clip, push it to one side to release it from the rivet.*

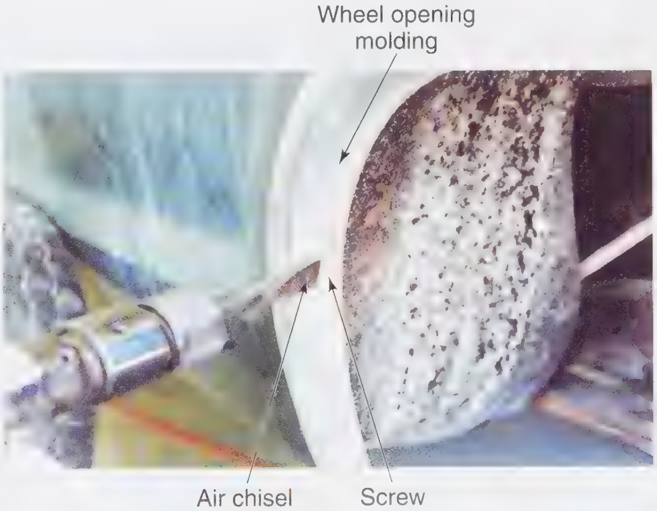


Figure 8-7. *An air chisel can be used to vibrate stubborn wheel opening molding screws.*

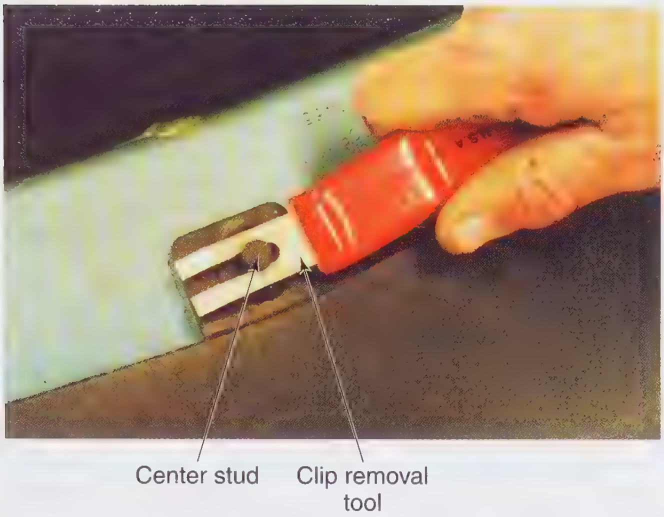


Figure 8-8. *To remove a plastic rivet, raise the center stud.*

Figure 8-9. *Removing the headlight assembly will allow access to the back of this damaged fender.*

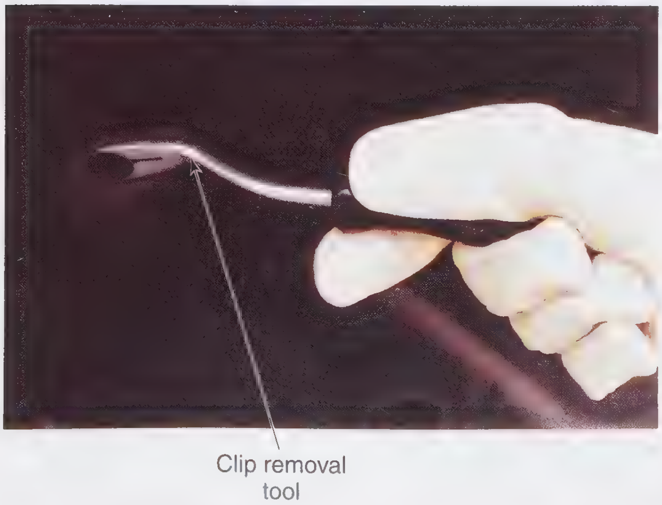


Figure 8-10. *Hood insulation pad clips can be removed using an upholstery tool.*

the screw heads. After removing any caps, remove the screws from the trim panel. After removing the screws, carefully pop out the clips that secure the trim panel to the door. These clips are located along the edge of the door panel.

On doors with manual windows, the window crank handle must be removed before the panel can be taken off. **Figure 8-11** shows how to slide the handle removal tool into place.

On vehicles with power door locks and/or power windows, the doors contain a wiring harness. You must disconnect the harnesses connector from the lock and window switches before removing the door trim panel. Remember that the plastic clips on the connectors can be easily broken, especially if they are old.

The front portion of a quarter panel on a two-door vehicle may be accessible from inside the passenger compartment. It may be necessary to remove the rear seat. The trim panel is removed by locating and removing the screws that hold it in place. Instead of screws, some vehicles use Velcro pads to hold the trim panel in place.

For access to the rear portion of the quarter panel, you must remove the trunk lining. Look at the arrangement of the lining to determine what needs to be removed first. Often the trim panels are overlapped.

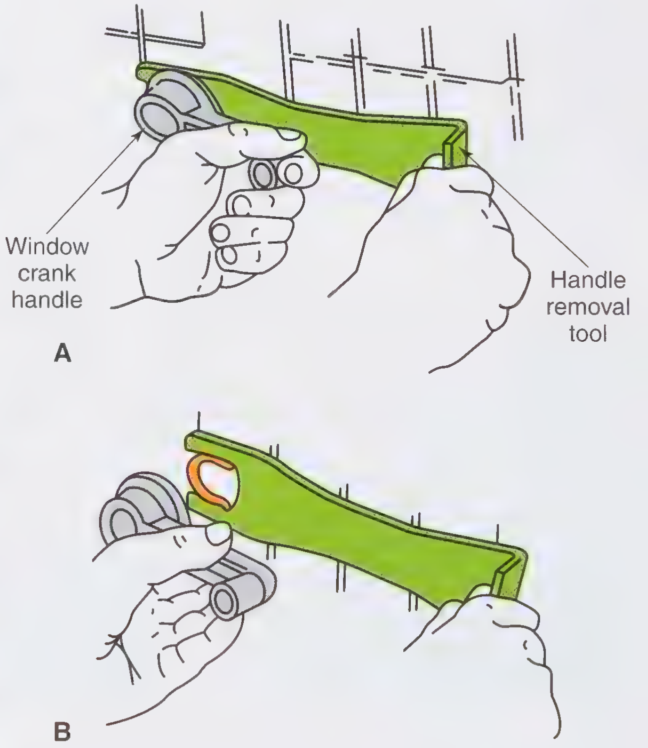


Figure 8-11. *The window crank handle may be secured with a clip. A—Slide the handle removal tool under the handle as shown to release the clip. B—Pull the crank handle from its shaft.*

To disassemble, remove the outermost trim panel first. Then remove those that are underneath.

In some cases, the headliner must be removed to access damage. The headliner is held in place by attachments on the roof and by the roof trim. To remove the headliner, remove the roof trim first. The roof trim consists of plastic panels that cover the A, B, and C pillars and outline the door openings. The trim may be held in place by screws, clips, Velcro, or a combination of these items. Begin by locating any screws holding the trim in place. In some cases, covers are placed over the screw heads to help conceal them. Remove any screws that are found. If no screw heads are present, pull on an edge of the plastic panel with your fingers and try to look under it. Do not use a screwdriver or other pry tool when removing the trim. Prying on the plastic panel with a tool may distort the plastic and leave a stretch mark. A stretch mark is a visible white band in the plastic panel. If you can see clips under the panel, pull the panel off by hand.

With the roof trim off, the headliner can be accessed. Carefully detach the headliner from the roof. The headliner may be attached to the roof with Velcro. Most headliners have a semi-rigid backing. Folding this backing will permanently crease the headliner. The left and right edges of headliner may be able to be rolled together slightly and removed from a hatchback vehicle. In regular-cab pickup trucks, the headliner can be taken out through a door. In other vehicles, the back glass or windshield may need to be removed. If the headliner cannot be easily removed, drop it down on the seats and leave it inside the vehicle while the roof is being repaired.

Roughing Out

The panel repair process can be divided into two steps: roughing out and finishing. Roughing out restores the damaged panel to its approximate contour, and finishing completes the repair by restoring the exact contour of the panel. Several operations may be involved in the roughing out phase, including pulling, pushing, stretching, leveling, raising, edge alignment, and shrinking, as well as picking and filing.

Pulling

Longitudinal force can shorten a panel's overall length. A pulling operation can be used to lengthen the panel. Pulling will remove folds, restoring the panel's overall length. If a corrective force is applied at the point of impact, folds from longitudinal force can be removed as the panel is lengthened. See **Figure 8-12**.

Lateral force can also shorten a panel by drawing the edges inward. A pulling operation relies on the lift reaction to restore panel dimension as the damage is pulled out. The ***lift reaction*** means that as the panel lengthens, the buckle unfolds, or straightens. A pull will always try to form a straight line between the pull location and the anchor location on the vehicle.

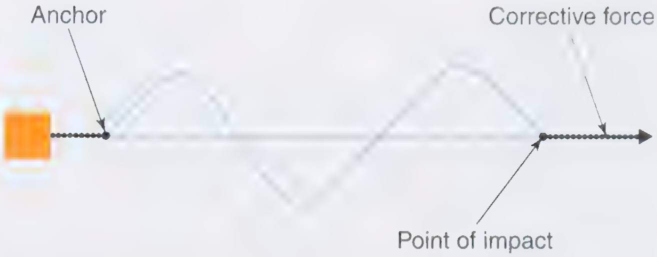


Figure 8-12. *Folds can be removed from longitudinal damage by exerting a corrective force that restores panel length.*

The lift reaction has the greatest effect when there is a small angle between the attachment and the pull. When the angle is large, the lift reaction has less effect. See **Figure 8-13**.

To set up a pull, an attachment is needed. An ***attachment***, or ***hookup***, connects the vehicle to the pull. The quickest and simplest attachments are hooks. See **Figure 8-14**. Hooks are placed on the back side of the panel and a corrective force is applied to pull the hook and the panel. The surface area of the corrective force is the same size as the contact end of the hook. If the metal where the contact end of the hook is attached is weaker than the damage, the corrective force will bend the contact area instead of pulling out the damage. A large contact area is less likely to cause damage and is preferred to a small contact area.

Bolts, washers, and nuts placed in existing holes can also be used as attachments for pulling. The vehicle shown in **Figure 8-15** was hit in the rear corner and

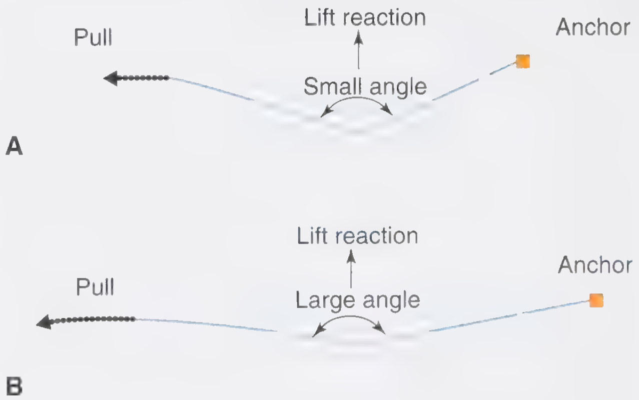


Figure 8-13. *A—A small angle gives a large lift reaction. B—A large angle gives a small lift reaction.*

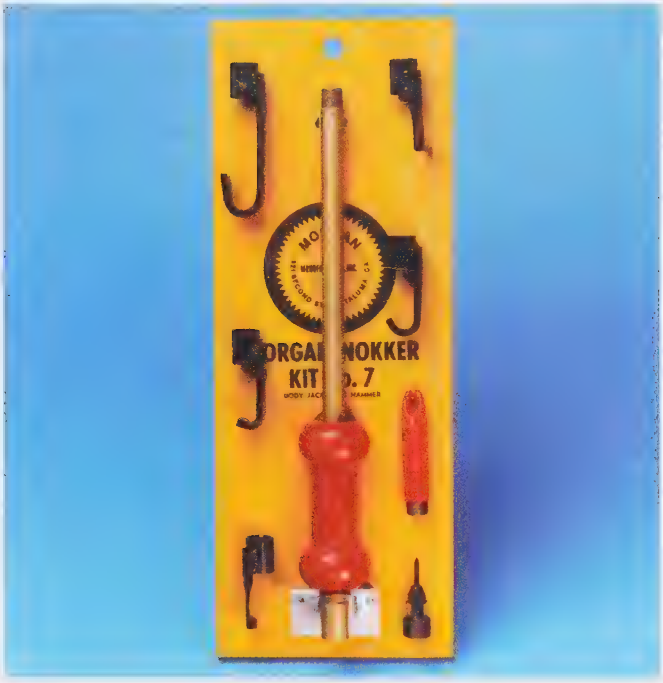


Figure 8-14. *Slide hammer hooks of different sizes can be used to make various pulls. (Morgan Manufacturing)*

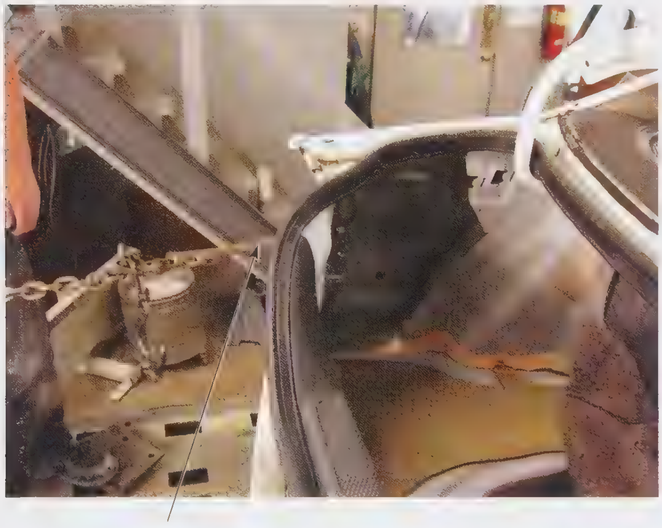


Figure 8-15. *To repair this vehicle, a threaded rod has been placed into the taillight hole and a washer and nut have been threaded onto the rod. The rod serves as an attachment for pulling out the damage.*

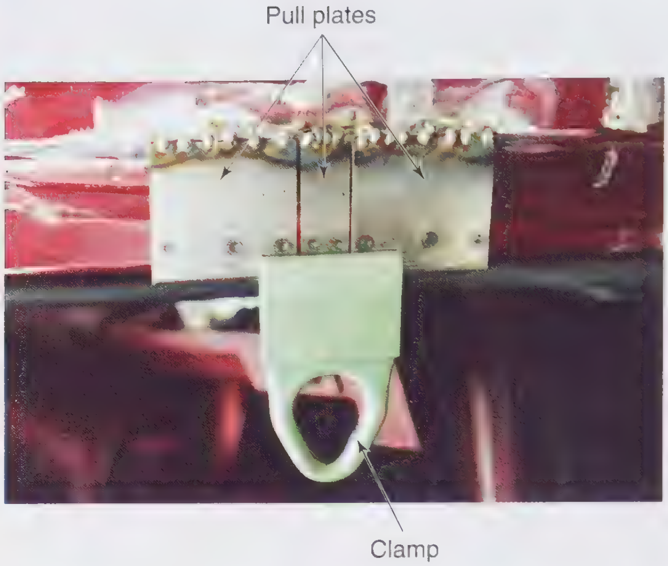


Figure 8-16. *A pull plate is welded to the damaged portion of this panel. The damage can then be pulled out with a self-tightening clamp and a hydraulic ram or a slide hammer.*

has folding damage on the quarter panel. Lengthening the panel will correct the damage. The attachment is made by inserting a threaded steel rod in an existing taillight hole. A washer and a nut are threaded onto the end of the steel rod. The corrective force is acting only on the surface area of the washer. As with hooks, the attachment area may be damaged if the folded area resists movement. If the folds do not move, the metal around the attachment holes may stretch or tear.

Another method of attachment is to weld a plate onto the damaged area. A piece of scrap sheet metal can be used, or specially made pull plates are available. **Figure 8-16** shows welded pull plates and a puller. The plates are MIG welded to the damaged panel. Be careful when welding, as excessive heat can further damage the panel. The pull is concentrated at the welds. More welds spread out the force of the pull. The pull can be made with a slide hammer or a hydraulic ram. The pull must always be parallel to the welds and the plate. If the pull is not parallel to the welds and plate, the plate will twist and may break.

There are two types of corrective force that may be used to pull an attachment: tension and shock force. ***Tension*** is a constant force that can be used to pull an attachment. A constant pull on a damaged panel will draw the damage in the direction of the pull. A frame machine with hydraulic rams or a come-along can supply a constant force.

A ***shock force*** is not constant. Instead, it is applied as a series of blows. A slide hammer is used to apply a shock force. There are advantages to each type of corrective force. A constant force works better on strong folds, but a shock force is easier to set up and is adequate for minor damage.

In order to apply corrective force, the ram or come-along must be hooked up to the vehicle and to a stationary object. The vehicle must be anchored to prevent it from moving. **Figure 8-17** shows a power post

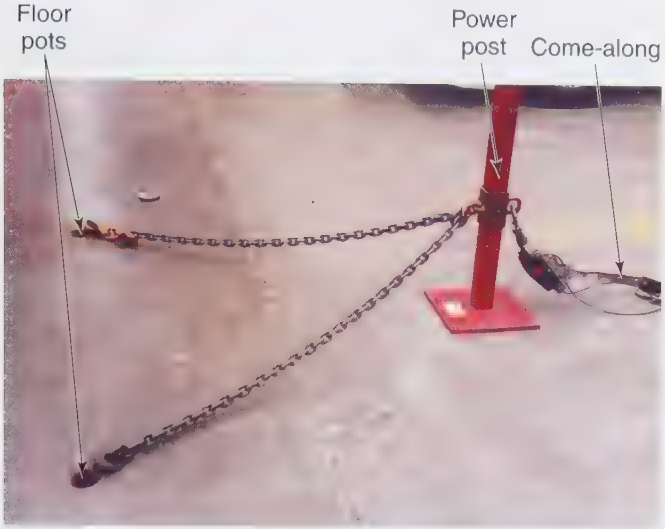


Figure 8-17. *This power post is chained to the floor for light sheet metal pulls.*

setup with chains and floor pot anchors. The come-along can also be anchored to the floor pots themselves. As the come-along handle is cranked, the cable pulls the damaged panel into alignment.

As we already know, a force will always move the weakest object. When the force is acting upon two or more objects (as with the come-along setup), the weakest object will move first. If the attachment to the vehicle is weak, it will give first. If the anchoring point is weakest, the anchor will give way. If the attachment and anchor are stronger than the damage, the damage will move first.

Figure 8-18 shows a hydraulic ram being used to pull out damage. The vehicle is anchored so it cannot move. Likewise, the hydraulic ram cannot move. As the chain is tightened between the vehicle and the ram, the damaged area will move, lengthening the panel.

The immobilizing position is important. Remember that a corrective pull will always try to make a straight line between the attachment and the pull. In most cases, a straight out pull is needed. This means that the pull should be at the same height as the attachment.

WORKING SMART

As tension is applied to an anchored vehicle, the suspension may sag. To prevent this load on the suspension, insert blocking under the vehicle to maintain vehicle height. Blocking will keep the vehicle at the proper height so the pull will work as intended.

Pushing

Pushing with a four-ton hydraulic power set applies a constant corrective force to align damaged panels. For example, in a unibody vehicle that has been hit in the rear, the power set can be positioned in the trunk to push out the damaged rear body panel and quarter panel. If a quarter panel has been hit from the side and is shortened in length, the power set can be positioned inside the trunk to push the quarter panel to proper length, causing lift reaction to remove the damage.

The power set ram requires a strong base. The force created by the ram not only pushes on the damage, but it pushes on the base as well. Remember that when force is applied, the weakest area will move first. Make sure the base is stronger than the damage. The ram should always be set up to rest on the base. Tubes are snapped onto the ram to reach the damage. **Figure 8-19** shows a typical setup inside a trunk. Notice that the base is the wheel house. The wheel house is

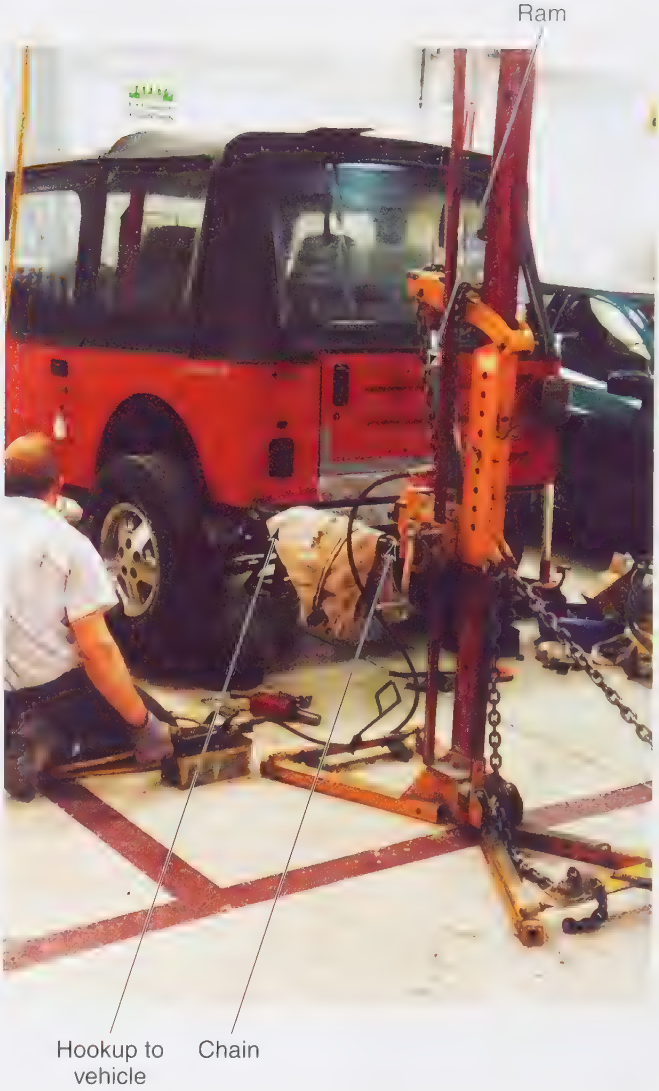


Figure 8-18. *The hydraulic ram on this pulling equipment provides a constant force to remove damage.*

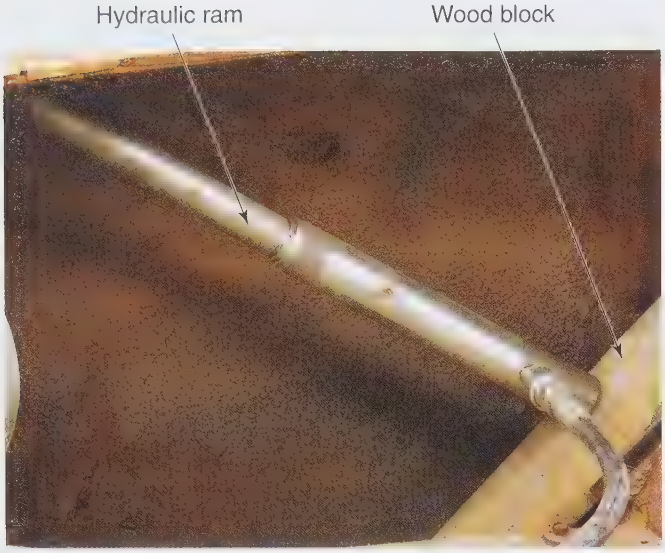


Figure 8-19. *This hydraulic ram rests on a block of wood positioned between the ram and the wheel house.*

curved and, therefore, may not be a stable base. To overcome this problem, a block of wood is placed on the wheel house and the base of the jack to spread out the force. At the damage correction end, a narrow attachment is installed. The narrow attachment can be used because the quarter panel overlaps the rear body panel. Because the damaged area is made of two overlapping panels, it is stronger and less likely to stretch than a single layer area. If the metal were a single layer, a broader tip would be used to prevent stretch. Once the body jack is in place, the pump is hooked up. Pumping the jack handle causes the ram is extend and push on the damage.

A body jack can be used to push out lateral damage, such as damage to a body line. A piece of angle iron can be used to concentrate the push on the body line. When using a body jack, remember that the base and the attachment must be broad enough to prevent additional damage.

The duckbill attachment can be used in confined areas to push out damage. For example, if a door is hit from the side, the duckbill attachment can be used inside the door to raise the damage. The duckbill consists of a stationary jaw and a movable jaw, **Figure 8-20**. The stationary jaw is placed against a strong base. The movable jaw contacts the damage. The movable jaw must contact the damaged area squarely. If only a corner of the jaw contacts the area to be pushed, stretch damage may result. If the jaw cannot be positioned to contact the damage squarely, spread out the force with a block of wood.

There will not be much travel in the movable jaw. It may be necessary to place wood blocks between the jaw and the damage to provide sufficient reach.

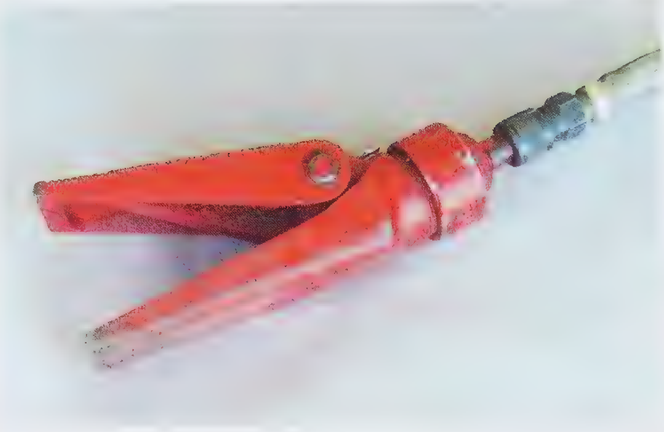


Figure 8-20. *The stationary jaw is located at the bottom on this duckbill attachment. The movable jaw is at the top.*

Stretching

When metal is upset, its surface area is reduced and its thickness is increased. ***Stretching*** restores the metal to its correct dimensions. To stretch metal, place a dolly on the inside surface of the damaged panel and use a stretching hammer on the outside surface. Hammering on the dolly causes the upset metal between the dolly and the hammer to thin out. This thinning is a rearrangement of the metal grains. As the metal gets thinner, its surface area is increased. The increase in surface area restores the proper dimensions to the upset metal. The dolly used for stretching must match the shape of the undamaged panel. Hold the dolly tightly against the upset metal. Hammer rapidly, with at least one blow per second. With each blow, the dolly should ring like a bell. Push the dolly out to meet each blow. When restoring the crown to an upset panel, stretch the panel starting from the ends and working toward the center. See **Figure 8-21**. If the center of the damage is raised first, the crown will not be restored.

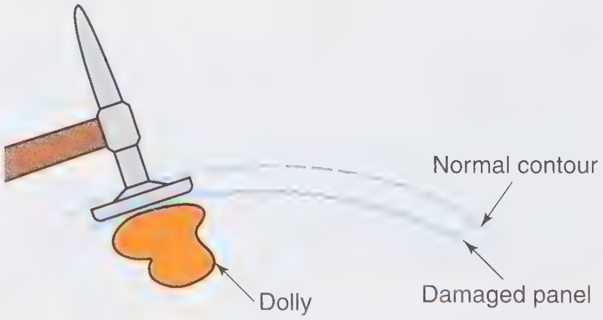


Figure 8-21. *This diagram shows how to stretch metal to restore crown. Using the hammer-on-dolly technique, start at the edges and work toward the center.*

Tight double folds caused by longitudinal force will also need stretching. With the damaged panel under tension, the folds can be stretched to restore length. Do not hammer on the folds until the tension force begins to unlock them. Hammering before tension unlocks the folds will create additional damage, making the folds even stronger.

An upset can cause false stretch, or "oil can," in an adjacent area. A ***false stretch*** is a bulge that pops in when pressed and out when released. To demonstrate false stretch, take a piece of paper and make a tear perpendicular to one edge. Overlap the edges of the tear. The overlap represents the upset, or decrease in surface area. The overlap causes a bulge in the paper adjacent to the overlap. On a vehicle, a decrease in surface area causes a bulge, or false stretch, in the adjacent low-crown area.

False stretch may be present before repairs begin or may appear during straightening. If false stretch is present, look for an upset in nearby metal. Removal of the upset by stretching will relieve the false stretch. The upset is often in an adjacent body line. If the back side of the panel is accessible, place a body chisel on the back of the body line and tap along the chisel's face from the outside of the panel. This will stretch the body line, relieving the false stretch.

If false stretch is present but an upset cannot be found, or if only the outside of the panel can be worked, locate the nearest body line. Use a dinging hammer to tap on the body line. This may relieve an upset that is present in the body line, causing the false stretch to firm up. If an upset cannot be located and tapping on the nearest body line does not work, the false stretch can be eliminated by shrinking. Shrinking techniques will be covered in detail later in this chapter.

Leveling

When high areas and low areas are found next to each other, ***leveling*** is used to raise the low areas and lower the high areas. If the damage did not cause a change in surface area, leveling will restore the panel contour.

During leveling, a dolly with the same contour as the undamaged panel is used under the low areas, while a flat-faced dinging hammer is used on the high areas. The dolly pushes up on the low areas as the hammer taps on the high areas. Think of the dolly as providing the direction of the movement and the hammer taps as providing the vibration for the movement. See **Figure 8-22**. The hammer does not beat the high area down. Instead, it vibrates the high area. This hammer-off-dolly technique causes the dolly to rebound and raise the low area. The tapping gradually lowers the high area.

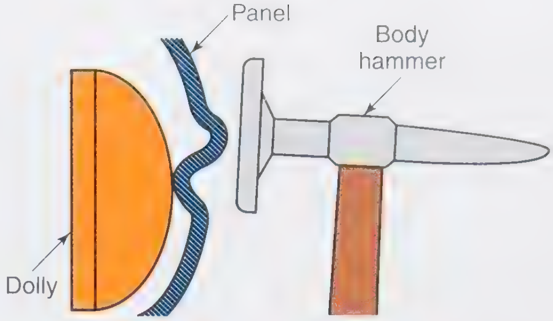


Figure 8-22. *This diagram shows the leveling process for a high-crown panel. (Toyota)*

A hammer-on-dolly technique with a dinging hammer may also be used to raise low spots. Light taps, not bell-ringing taps, will raise the metal without stretching. Light hammer-on-dolly blows can be used to level a folded flange. Reverse-crown areas can be leveled with a high-crown hammer, as shown in **Figure 8-23**. The high-crown hammer will fit into the reverse crown in order to lower a ridge.

Leveling can also be done on a low-crown panel during tension repairs. The damaged panel shown in **Figure 8-24** has minor folds caused by longitudinal force. The metal is pushed in at *B* and pushed out at *A*. As corrective force is used to lengthen the panel, the dolly is used to hold the metal out at *B*. As the metal moves at *B*, *A* will move also. Tapping with a hammer at *A* vibrates the metal and helps it move in to its proper contour. Leveling a low-crown panel requires less force than leveling a high-crown panel.

Raising

Low areas can be brought up with a ***raising*** operation. There are several techniques used to raise damage.

Figure 8-23. *A high-crown hammer can be used to level a reverse-crown area.*

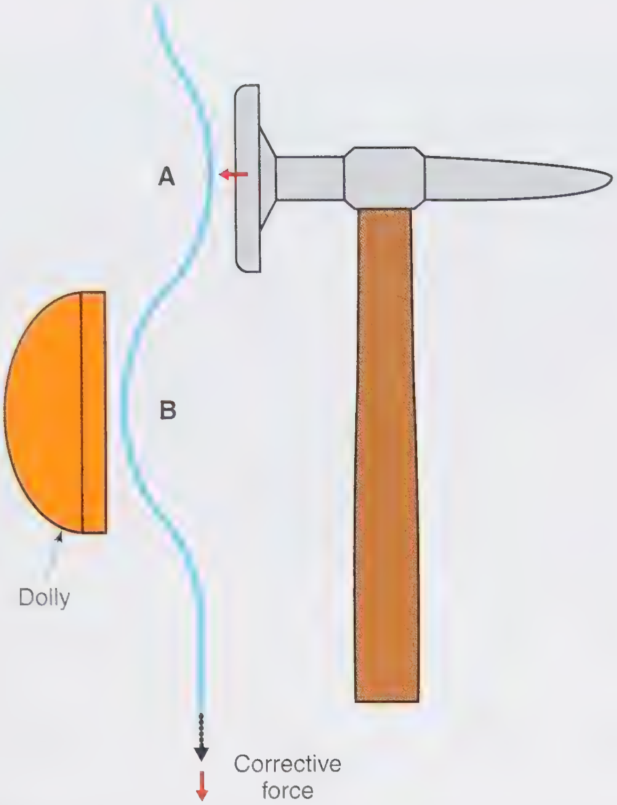


Figure 8-24. *When leveling with a hammer and dolly, tap on the highs and lows to vibrate the metal.*

One way to raise a low spot is to use a pry pick. Pry pricks are often used in confined areas or areas with limited-access, such as the inside of a door or fender. The pry pick is inserted from behind the panel to raise the low area. The pick needs a surface to rest against for leverage. Be sure this surface is strong. **Figure 8-25** shows how this process works.

Sharply pointed picks can easily pierce or stretch metal. Be careful. Round picks are less likely to pierce, but they can still stretch the metal since the force is concentrated in a small area. A pry pick is effective for raising small low areas.

One difficulty in using the pry pick is positioning the pick to raise the correct spot. This requires good eye/hand coordination, because when the pick is placed inside the panel, it is hidden from view. Unintentional raising of an undamaged area will cause stretching. To test for the correct location, insert the pick and slightly raise the metal. Watch for movement on the outside of the panel. Adjust the location of the pick as needed to raise the right spot. Carefully push the metal out with the pick.

Gradually restore the crown, starting at the ends and working toward the center of the damage. Raising a single point from the center of the low area can cause problems on a high-crown panel. See **Figure 8-26**.

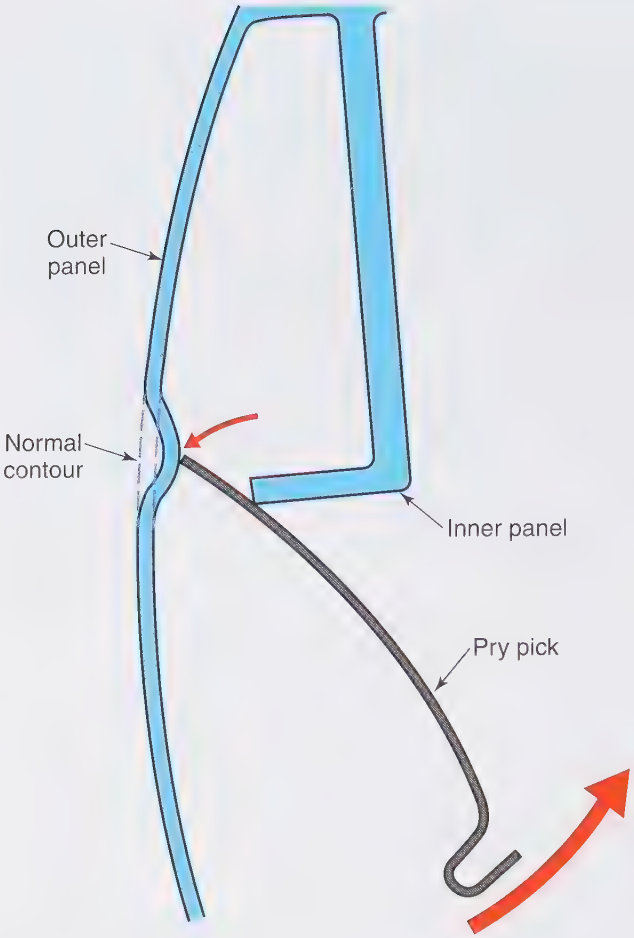


Figure 8-25. *A pry pick can be used to raise low areas. The pick uses the inner panel for leverage. This setup can easily stretch metal, so raise the low area gradually.*

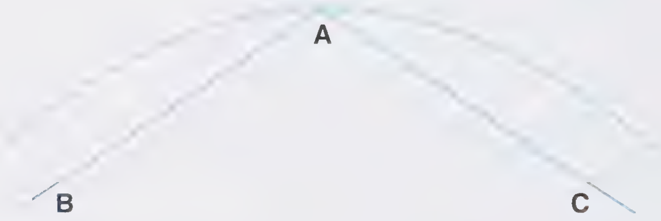


Figure 8-26. *Raising the panel at point A will not restore the crown. Instead, raising at point A will tend to form a straight line between point A and points B and C. This may raise point A to the proper height, but it will not restore points B and C. To restore crown, raise points B and C; then gradually work toward point A. This requires some stretching of the metal.*

Another way to raise metal is to use welded-on draw pins. This method does not require access to the back side of the panel. In this method, the low area is stripped to bare metal. Draw pins are then welded to the low area as shown in **Figure 8-27**. The pins can then be raised

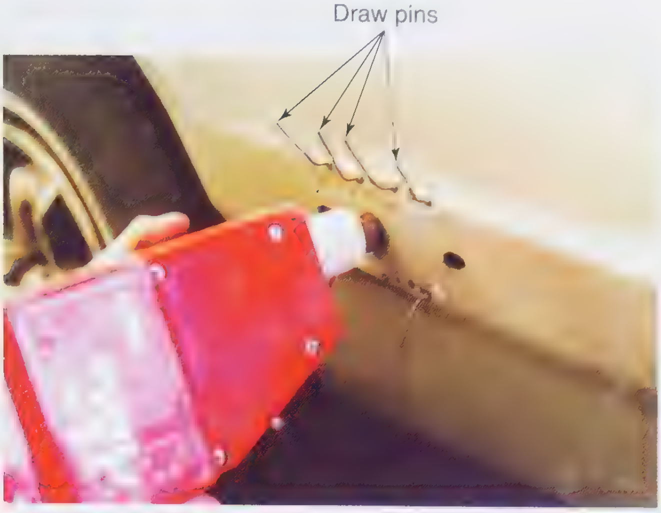


Figure 8-27. *Draw pins are welded to this panel to raise a low area.*

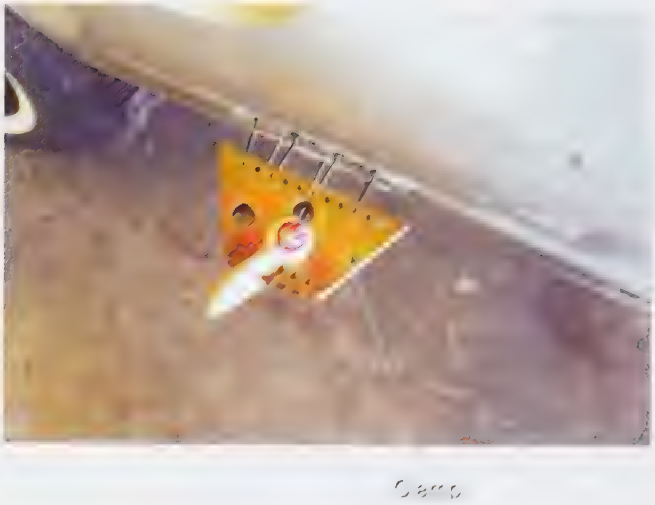


Figure 8-28. *Several draw pins can be raised at one time with this clamp.*

with a slide hammer or a T-puller. This method is fast and effective. However, it is easy to pull the metal too far, creating a high spot. The high spot will be work hardened and difficult to lower.

If the draw pin welder's trigger is held down too long, the pin will be welded deep into the metal. This may make the pin weld so strong and the surrounding metal so weak that when the pin is pulled, the metal surrounding the weld will break. When this occurs, the hole must be filled. A MIG welder can be used to fill the hole. After filling, the built-up weld is then ground flush. Another way to fill the hole is to use waterproof filler. The filler can be applied to the low area, filling the hole from the outside of the panel. The filler can also be applied from the back side of the panel. If the hole is accessible from the back side of the panel, remove the paint from the back of the panel. Then apply filler to the back side to bridge the hole. With either filler method, the back side of the repair should be sprayed with epoxy primer and rust proofing.

If a crease must be raised, several draw pins can be welded close together along the crease. A gang clamp can then be used to grab onto the pins, as shown in **Figure 8-28**. The clamp can be pulled with a slide hammer or a come-along. After the damage has been raised, the pins are removed by clipping them with side cutters and then grinding off the remaining heads. Instead of pins, washers can be welded to the panel and then pulled. W-shaped wire can also be welded onto a panel. The W-shaped wire can be welded to a body line or a crease. The wire is then raised with a claw handle. See **Figure 8-29**. For greater pulling power, a 10-pound slide hammer can be attached to the claw handle.

A damaged body line can be raised with a body chisel. This requires access to the back of the panel. The chisel face, if sharp, should be covered with masking tape. This will prevent it from cutting into the metal. To raise the body line, simply find the lowest point, place the chisel on it, and hit the chisel with a ball peen hammer. A body line is a strong area. A damaged body line is even stronger. Light blows will probably not move the body line enough to make a difference. Hard blows are generally needed to move a damaged body line. As you move the body line, check the progress on the outside of the panel. If arrowheads are present in the metal above and below the body line, they can be released once the body line has been roughed out.

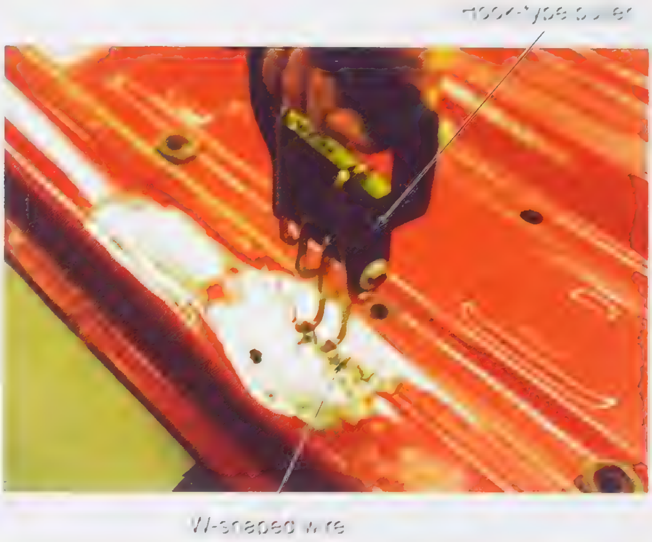


Figure 8-29. *W-shaped wire can be welded in a gouge. The wire is then pulled to raise the damage.*

Edge Alignment

Edges of doors or fenders can be pushed in during an impact. **Figure 8-30** shows a fender edge that has been pushed inward relative to the door. A slide hammer can be used to pull out the fender edge. An L-shaped attachment is placed along the edge of the fender. Tapping with the slide hammer, as shown in **Figure 8-31**, will raise the edge of the fender so it is flush with the door. Note that there is no buckle to remove in this example.

The door in **Figure 8-32** has been pushed in and has buckled. The edge of the door consists of three layers of metal: the inner structure, the inner hem flange, and the outer hem flange. Therefore, the edge of the door can be quite stiff when buckles form. To remove the damage, the edge should be raised as the buckle is worked. An L-shaped attachment is placed on the damaged edge. As one technician uses the slide hammer to remove the damage, another technician taps on the buckle.

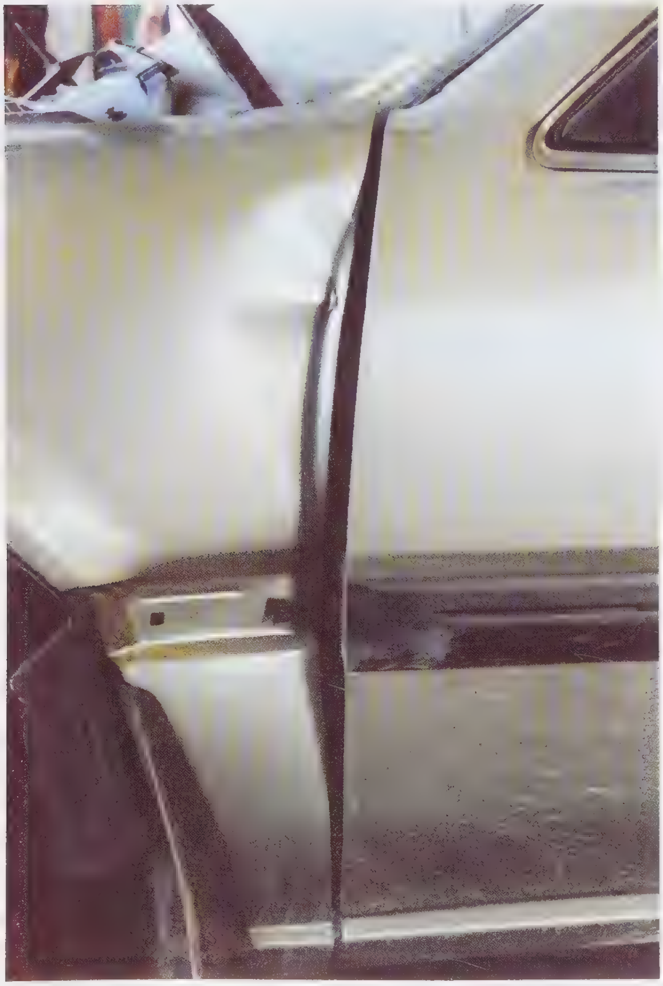


Figure 8-30. *This fender was driven back by a front impact. Opening the driver's door caused damage to the fender.*

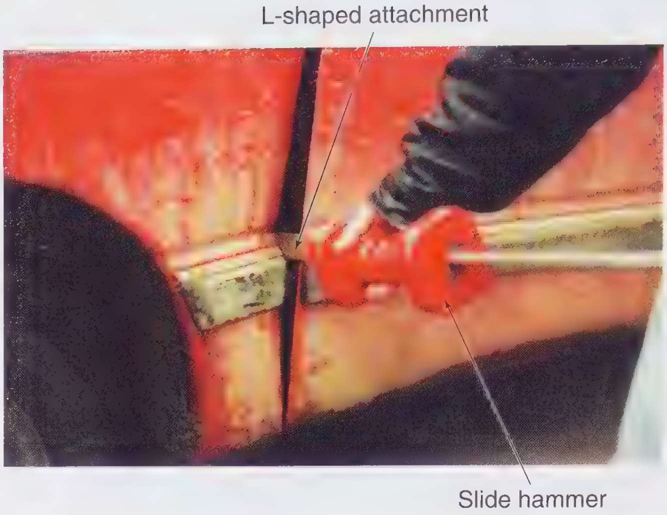


Figure 8-31. *When using a slide hammer to move a fender edge, line up the hook at the body line.*

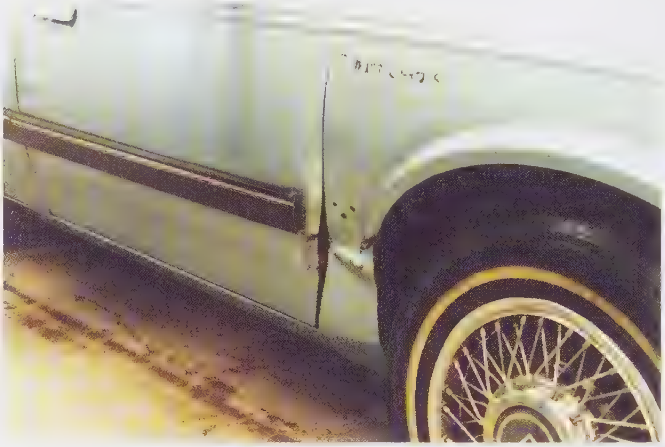


Figure 8-32. *The edge of this door has been pushed in and has buckled.*

This task can be accomplished by one technician. Instead of slide hammering, the technician can pull on the shaft of the slide hammer while tapping the buckle. Another method is shown in **Figure 8-33**. In this case, the door must be removed. Locking pliers are used to align the edge of the door. Pulling up on the locking pliers straightens the edge of the door. The hammer is used to tap on the buckle. The low area behind the buckle can be raised with draw pins.

Shrinking

Shrinking reduces the surface area of stretched metal. Shrinking can also remove false stretch. One way to reduce the stretched metal's surface area is to apply heat. Heat, even the small amount generated by a draw pin welder or grinder, will cause the stretched metal

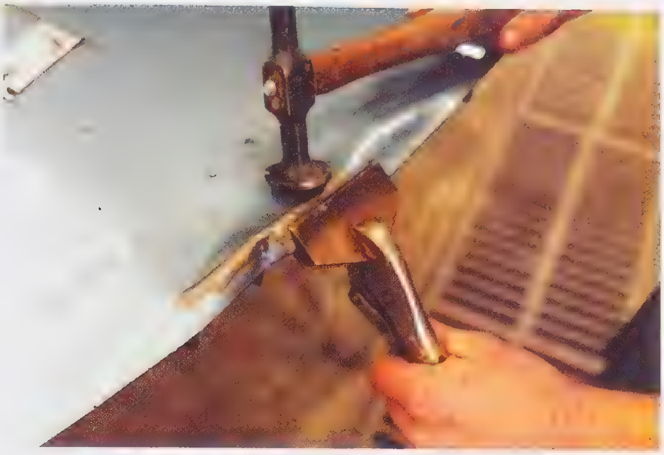


Figure 8-33. *The first step in this repair is to align the door edge with locking pliers. Tapping on the ridge while pulling the pliers will move the edge.*

grains to thicken. The thickening causes a reduction in surface area, thereby eliminating the stretch.

The amount of metal shrinkage that occurs depends on the size of the heated area and the heating temperature. The heating process must be carefully controlled. Stretch damage most commonly occurs on low-crown panels. Uncontrolled use of heat on a low-crown panel will cause warp damage. ***Warp damage*** is a group of high and low areas in a panel. Warp damage is difficult to remove, if not impossible. Always use the minimum amount of heat required when shrinking.

One heat shrinking technique commonly used to eliminate false stretch involves the use of a draw pin welder and a shrinking tip. If a shrinking tip is not available, simply use the draw pin welder without a pin. If hammering on a nearby body line does not cure false stretch, heating with the draw pin welder will remove it. Locate the false stretch and pop it in. Grind or sand off the paint from the false stretch area.

Push the shrinking tip onto the false stretch and pull the trigger on the draw pin welder. Keep the welder on for about one second. The false stretch should remain down and not pop up. If it does pop up, repeat the procedure. If the false stretch is so big that pushing in on one area causes another area to pop up, try shrinking the metal between the two areas. Usually, a false stretch area that has been shrunk must be filled.

You can also shrink a high spot using a draw pin welder and the draw pin welder tip (or a shrinking tip). Simply place the tip on the high spot and press the trigger in for one second. Then tap the heated area twice with a flat faced dinging hammer and immediately cool the heated area with a wet rag. This method works well on high spots that result from pulling draw pins above the surrounding metal.

Another shrinking method involves the use of an oxyacetylene torch or a butane-fueled micro torch to remove a low spot. This procedure will require heating, putting down the torch, and using the hammer and dolly, all in a brief period of time. Therefore, a dinging hammer, a flat dolly, and a wet rag should be nearby. Be sure to locate a safe place for the hot torch before you start. The stretched area should be stripped to bare metal first. When using an oxyacetylene torch, use a small tip, such as a #1 tip. Light the torch and adjust it to a neutral flame. The hot spot of the flame should be concentrated on the deepest part of the stretch. The heated area must be no bigger than a dime. See **Figure 8-34**. As steel heats up, its color changes from silver to blue and then to red. The heating will cause the grains to thicken, reducing the surface area. With less surface area, the metal contracts, raising the low spot. Immediately after the steel changes color from blue to red, turn off the torch and set it down. Tap around the heated area with the dinging hammer. If the back side of the panel is accessible, the dolly can be used to support the panel. Use light hammer-off-dolly blows to level the area. Once the color has disappeared, the wet rag can be used to cool the area. Using the wet rag to cool the area while the metal is too hot with color can make the metal brittle. The area that has been shrunk will be harder than the surrounding metal. If many shrinks are needed, shrink the most stretched area first, but do not quench it (cool it with the wet rag). Shrinking with heat will burn rustproofing from the back side of the panel. Be sure to replace the rustproofing after heat shrinking.

As damaged metal is straightened, a stretched area, originally a low area, may become raised. The area is still stretched, but it is now high instead of low. A torch can

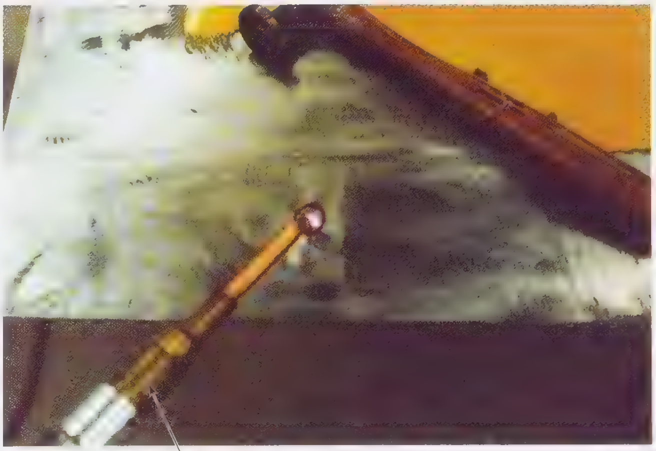


Figure 8-34. *A torch is used to heat a small circle on a stretched panel. Notice the color of the heated metal.*

also be used to shrink a stretched high spot. Locate the highest part of the stretch. This area will have the most stretch. Shrink this area first. Heat up the area with the most stretch until it just reaches a red color. The heated portion should be no larger than a dime. Put the flat dolly on the back side of the panel. Use light off-dolly taps around the heated area. Continue tapping until the heated area has cooled enough to touch. Next shrink the highest remaining area. This will gradually lower the stretched high area.

An oxyacetylene torch (with a small tip) or a butane micro-torch can also be used to remove hail dents from a low or medium crown panel. The flame should barely touch the deepest part of the dent. The heated metal expands but is restricted by the surrounding cold metal, so it moves up. This upward movement may be enough to eliminate the dent. If not, repeat the process. See **Figure 8-35**.

Another shrinking technique does not use heat. Instead, the stretched metal's surface area is reduced by ***kinking***. Kinking involves the use of a shrinking hammer (serrated-faced hammer) or a sharp pick hammer to reduce the surface area by gathering the metal together. To use a shrinking hammer, push up on the stretched low spot with a flat dolly. Tap the bulge with the shrinking hammer. Hammer taps should be off dolly but close to the dolly's edge. You will notice that the serrations on the hammer face produce small kinks on the metal's surface. Continue tapping until the metal is level.

To use a pick hammer for shrinking, place a flat dolly on top of the stretched area as shown in **Figure 8-36**. Tap up on the stretched metal with the pick hammer. The dolly prevents the metal from moving too far. The pick hammer raises and shrinks the metal at the same time.

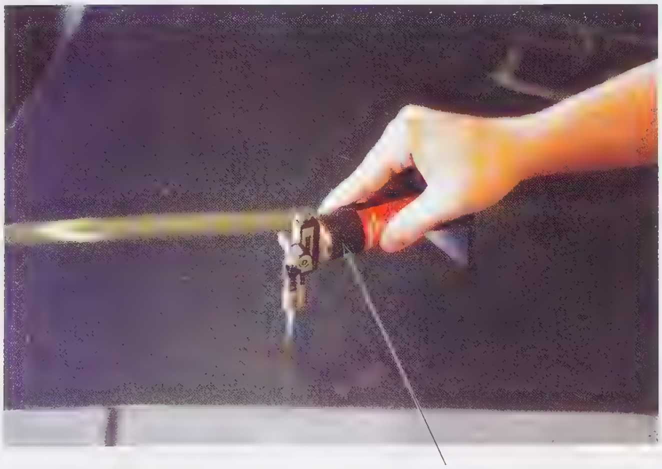


Figure 8-35. *A butane-powered torch can be used to raise small hail dents.*

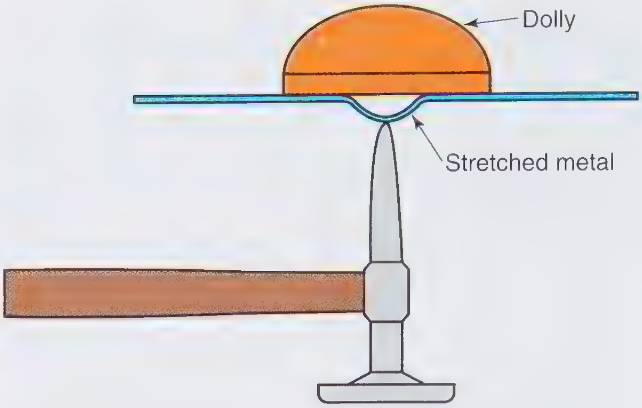


Figure 8-36. *Kinking with a sharp pick hammer will reduce surface area in stretched metal.*

Beginners often encounter problems when repairing a low-crown panel, such as a hood. Consider the front of a hood that is damaged, bumped, and filled. The technician may find a high area around the sanded filler. As the next step, the high area is tapped down; then more filler is applied and sanded. Another high area is discovered adjacent to the filler's edge. The tapping, filling, and sanding process is repeated. This is called ***chasing the dent.*** Chasing the dent occurs because the low-crown metal is floppy and is easily pushed in. The pressure from sanding causes the floppy metal under the filler to be pushed down.

To prevent chasing the dent, tighten any floppy metal around the area to be filled by making a shrink fence. A ***shrink fence*** is simply a line of small kinks made with a sharp pick hammer. See **Figure 8-37**. The shrink fence tightens the floppy metal in the low-crown area, allowing the filler to be sanded level.

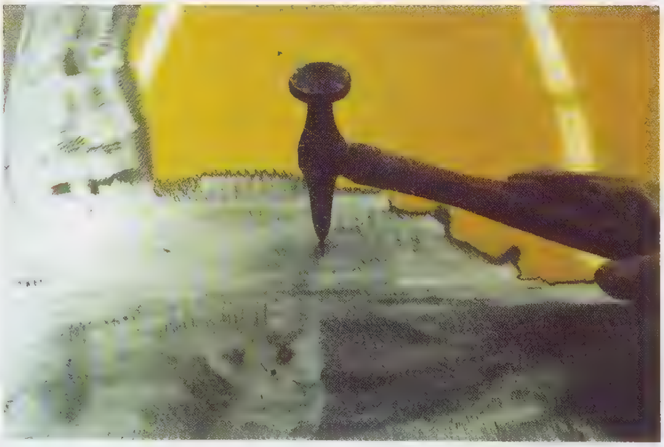


Figure 8-37. *A pick hammer is used to make a shrink fence in a panel.*

Technicians sometimes oversand the filler. The excessive sanding leads to undercutting, a condition in which filler is sanded below the level of the adjacent metal. When comparing the filler height to the height of the adjacent metal, the technician misdiagnoses the undercutting problem and taps down the adjacent metal rather than refilling the low area. Undercutting should not be confused with chasing the dent.

Picking and Filing

Picking and filing are operations performed at the end of the roughing out process. ***Picking*** raises small lows and lowers small highs. ***Filing*** is used to identify high areas and low areas. Both sides of the panel must be accessible for picking and filing.

A body file is flat or nearly flat. Files should be used on flat surfaces. On a panel with single crown, the filing should be done with the flat surfaces as shown in **Figure 8-38**. On a double-crown surface, the filing should be short so as to not cut into a crown. The file is held at a slight angle as it is pushed away from the technician's body. Do not contact the metal on the return stroke. The file bites into the high areas and passes over the low areas. A couple of passes with the file will make bright shiny areas in high spots. You can see file marks on these spots. Also you can feel the high areas when filing. The file will drag when it hits a high area.

After locating high areas, tap them down with a pick hammer. If the pick hammer is sharp, the area moved will be small and precise. A blunt pick hammer can be used to lower larger areas. When the high area has been removed, file the panel again. If the file glides across the panel without dragging or cutting into a high spot, look for low areas. Low areas are places that do not have any file marks. Low areas should be brought up from behind with a pick hammer. This process is called ***blind picking***. A sharp pick hammer may raise a low spot up to a sharp point. If the sharp point is filed, the file may cut the top off the point, leaving a hole in the metal. To prevent this type of problem, do not raise the low spot above the surrounding metal.

A bull's-eye pick, **Figure 8-39**, can be used instead of blind picking. A ***bull's-eye pick*** has a sharp pick point that the technician controls by pulling on the handle. Pulling on the handle causes the pick to hit inside the bull's eye. This is a very accurate alternative to blind picking. Simply align the bull's-eye over the low spot and pull the handle. The pick will raise the low spot.

Additional filing and picking can be done to make the panel level. Do not file an excessive amount of metal from the panel. Doing so can make the panel too thin. If you plan to fill the low areas, stop picking and filing once all the high areas are level and the low areas are less than 1/8" (3.2 mm) deep.

A grinder can be used instead of a file during finishing operations, as shown in **Figure 8-40**. A grinder can be stroked back and forth over the panel. If the grinding disc is held flat to the surface, it will identify the high and low areas, as a file would. A grinder will produce heat, so only use a grinder in this way on high-crown panels. As with a file, find and tap down the high areas and then raise the low areas.

Roughing out Specific Types of Damage

This section details the procedures for roughing out specific types of damage. Roughing can be performed as a one-sided repair or a two-sided repair. In a ***one-sided repair***, only the outside of the panel

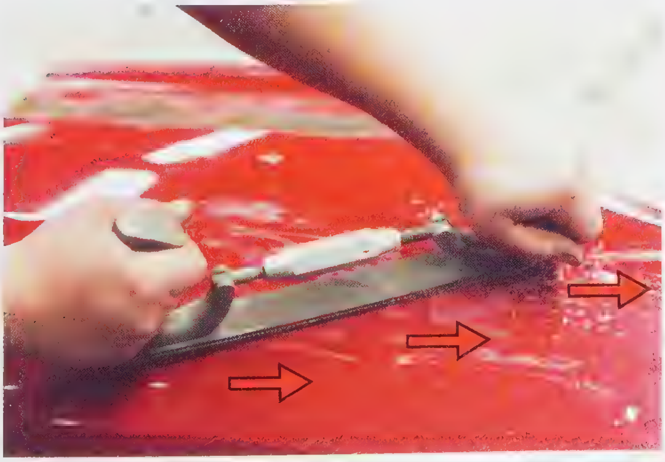


Figure 8-38. *When filing on a single crown panel, hold the file as shown here.*

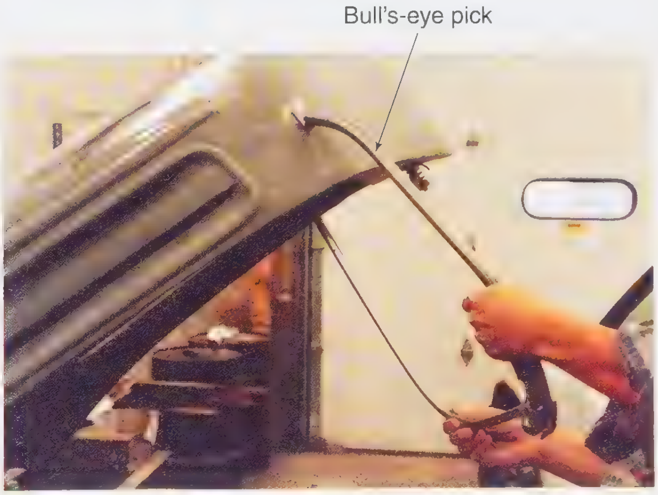


Figure 8-39. *A bull's-eye pick is being used to raise a low spot on a vintage hood.*

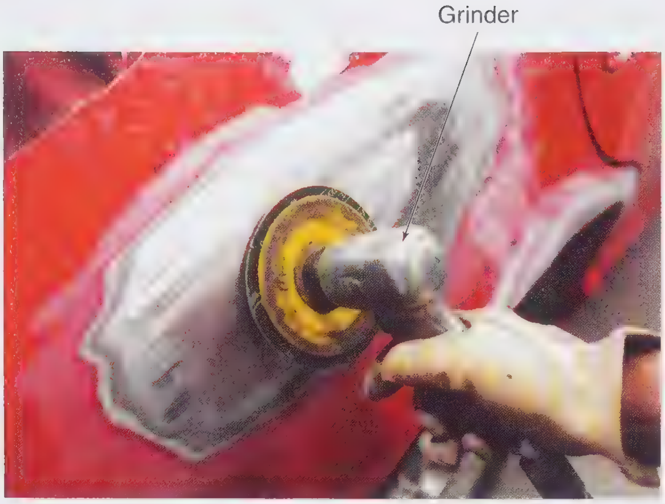


Figure 8-40. *Grinding across the panel will help you identify high spots.*

is worked. This type of repair is performed when the damaged panel is boxed, such as a quarter panel in front of the rear wheel, or if accessing the back side of the panel is difficult or time consuming, such as a door panel. In a ***two-sided repair***, both sides of the panel are worked. Access to the back side of the panel is required in a two-sided repair. An example of a two-sided repair is damage to a quarter panel behind the rear wheel. In this example, the back of the panel is accessible through the trunk. Keep the following points in mind when reading this section:

- If an internal brace or frame rail is damaged, it must be straightened before the panel is roughed out. Braces are strong and will resist the corrective force applied to the damaged panel.
- If a change in length is present, the panel must be lengthened. As the length is restored, the buckles can be released.
- Buckles must be released before displaced metal is raised.
- The metal in buckles and displaced metal belongs somewhere. The purpose of roughing is to move the metal to the right location.

Dents

Dents are caused by lateral force on low-crown panels. When repairing a dent, care must be taken to prevent stretching. Additionally, shrinking may be required. The following sections, will explain how to make several types of dent repairs.

One-Sided Repair, No Body Line

In this type of repair, roughing will prepare the panel for filler. Low areas less than 1/8" (3.2 mm) deep will be left in the repair area. The procedure for raising a one-sided dent that does not involve a body line is as follows:

1. Raising—Use a DA sander to remove the paint from the low area. A grinder would produce too much heat. Weld a draw pin to the lowest part of the dent and use a T-puller to pull up the low area. See **Figure 8-41**. Because the damage in this example is small, a slide hammer is not needed. Do not pull too hard, or the damaged area will be raised too much. To raise larger areas, use multiple pins and a slide hammer.
2. Leveling—As the draw pin is pulled up, tap the high area around the low area with a dinging hammer. The draw pin supports the low area, taking the place of a dolly. As the high area is tapped down, the low area is brought up.
3. Shrinking—To prevent chasing the dent across the panel, use a sharp pick hammer to create a shrink fence around the area to be filled.

One-Sided Repair, Body Line

When performing a one-sided repair that involves a body line, the body line should be raised first. The body line is the strongest part of the damage. Most of the damage adjacent to the body line will be raised with the body line.

The steps in performing this type of repair are as follows:

1. Raising—Remove the paint from the low area. Weld a line of draw pins to the body line. W-shaped wire may also be used. Attach a gang clamp to the pins and attach a slide hammer to the gang clamp. See **Figure 8-42**. Pull, slide hammer, or use a combination of pulling and slide hammering to raise the body

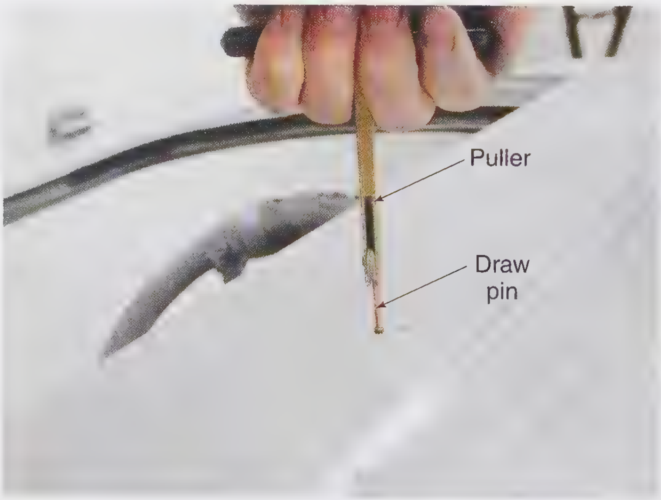


Figure 8-41. *A T-puller can be used to raise a small low area.*

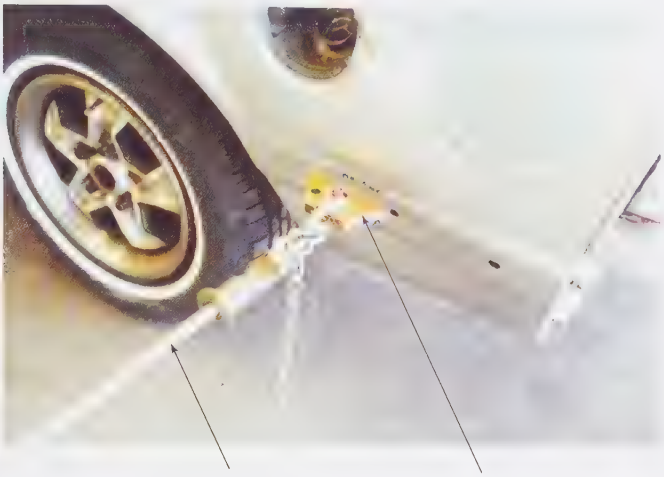


Figure 8-42. *The body line is the strongest part of the damage. The shaft of a slide hammer is shown pulling the body line.*

line to within 1/8" (3.2 mm) of its proper height. Try pulling first because the force is more controllable. If a gang clamp is not available, weld a draw pin to the lowest part of the body line and pull up the body line. Continue this process, working the next lowest portion, until the entire damaged area has been raised to within 1/8" (3.2 mm) of its proper height. Be careful not to raise the body line too high. If this does happen, support the surrounding metal as shown in **Figure 8-43** and tap the body line down.

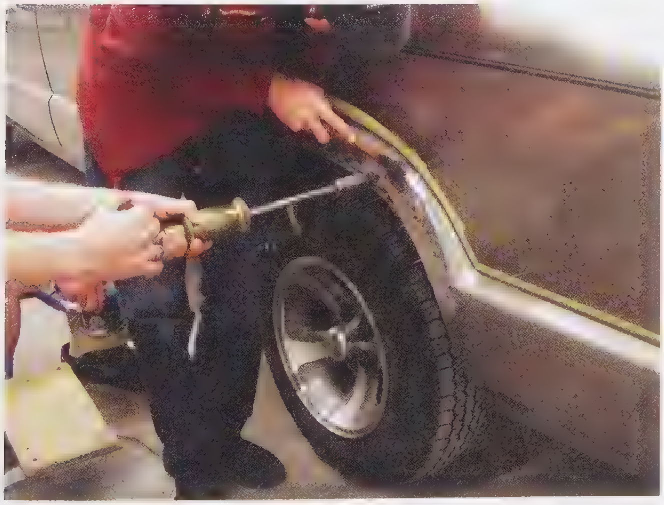


Figure 8-43. *The body line on this panel has been raised a little too high. Pulling on the draw pin with a slide hammer will help support the panel while tapping the body line down.*

2. Leveling—Use a dinging hammer to tap down the high spots around the low area. Pulling on the draw pins holds the panel in place, preventing it from moving down while tapping with the hammer. This is similar to the way a dolly supports a panel while hammering off dolly.
3. Stretching—The heat of the draw pin welder may compound the problem of upset on the damaged body line. If false stretch is present, lightly tap on the straightened body line. This may eliminate the problem.
4. Shrinking—To prevent chasing the dent, tighten the metal around the area to be filled with a shrink fence. The shrink fence may also correct a false stretch. If false stretch is still present after the shrink fence is made, try raising the body line. If the body line cannot be raised further, use the draw pin welder to shrink the false stretch.

Two-Sided Repair, No Body Line

In a two-sided repair that does not involve a body line, both the inside and outside of the damage are worked. The main concern is to prevent additional stretch to the panel. This type of repair is performed as follows:

1. Raising—Use a dolly that is large enough to span the dent and that has the same contour as the outside of the panel. See **Figure 8-44**. If the dolly spans the dent, it will prevent raising the metal too high. Tap the dent with a pick hammer. Do not hit the dolly hard enough to make it ring. Light blows are best. Gradually raise the dent. If a dolly is not available, raise the dent by blind

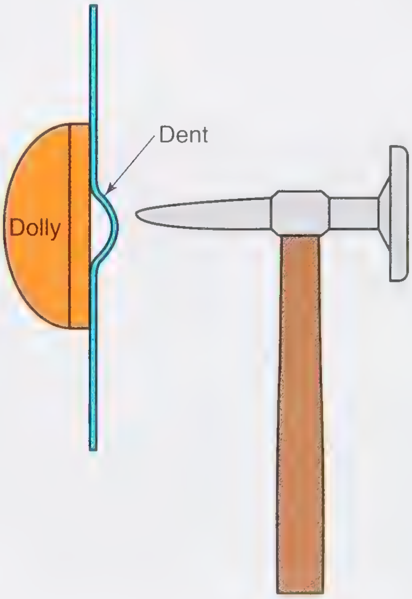


Figure 8-44. *Raising a dent with a pick hammer also shrinks the panel.*

picking. Be very careful using this method. The picking will reduce the surface area of the dent.

2. Picking and filing—File across the dent. Bright shiny areas indicate high spots. There may be a high spot surrounding the dent. Lower the high spots by picking, while supporting the panel from underneath with a dolly. Do not hit the dolly when picking.

Two-Sided Repair, Body Line

When performing a two-sided repair that involves a body line, the body line is the strongest part of the damage and, therefore, must be corrected first. Most of the damage in the low-crown area will be raised with the body line.

The steps in performing this type of repair are as follows:

1. Raising—Raise the body line with a body chisel. See **Figure 8-45**. The body line will resist movement, so hard blows on the chisel may be required to raise the body line. Make sure to raise the body line to its proper height.
2. Stretching—Damaged body lines are often upset. To correct the upset and false stretch, place the chisel on the back side of the body line and push out. From the outside, lightly hammer on the chisel to stretch out the body line.
3. Picking and filing—File across the damaged areas adjacent to the body line. Look for shiny spots that indicate high areas. Lower the high areas by picking, while supporting the panel from underneath with a dolly. Do not hit the dolly when picking.
4. Shrinking—Make a shrink fence around the area to be filled to prevent "chasing the dent" across the panel. The shrink fence will tighten up the metal.

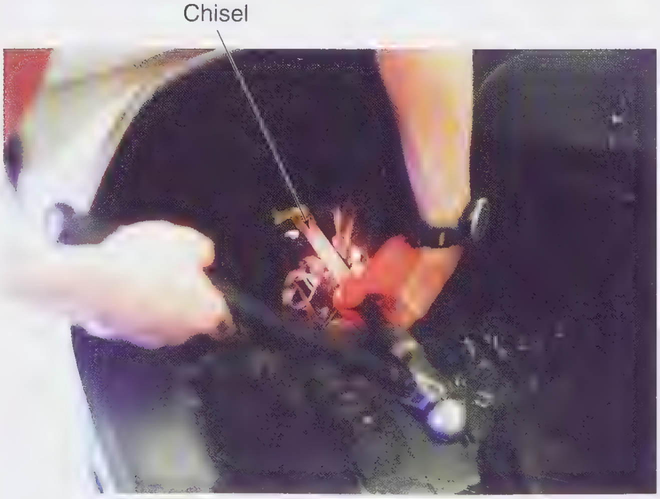


Figure 8-45. *A body chisel is used to move the body line out. Note that the face of this chisel is covered with green masking tape to prevent it from cutting the metal.*

Arrowheads

Arrowheads are caused by lateral force on a high-crown panel. The arrowhead is an area of upset. The strongest part of the damage is the area at the point of the arrowhead. See **Figure 8-46**.

One-Sided Repair, No Body Line

The steps in performing a one-sided arrowhead repair that does not involve a body line are as follows:

1. Raising—Remove the paint from the repair area. Weld draw pins in the low spots at each arrowhead. See **Figure 8-47**. Starting with the upper left pin and working clockwise, pull each pin out slightly with the slide hammer. Repeat the sequence, gradually pulling up each pin. Continue working the pins up, being careful not to pull the damage too high. Once the damaged metal is raised to within 1/8" of its proper height, begin the leveling process.
2. Leveling—While pulling out with the slide hammer, tap down the ridge around the arrowhead with a flat-faced

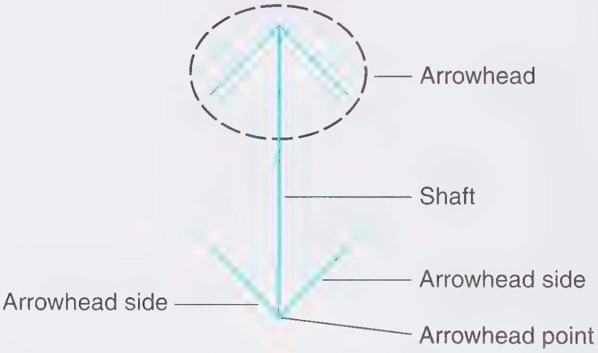


Figure 8-46. *These are the parts of an arrowhead. The point of the arrowhead is the strongest part of the damage.*

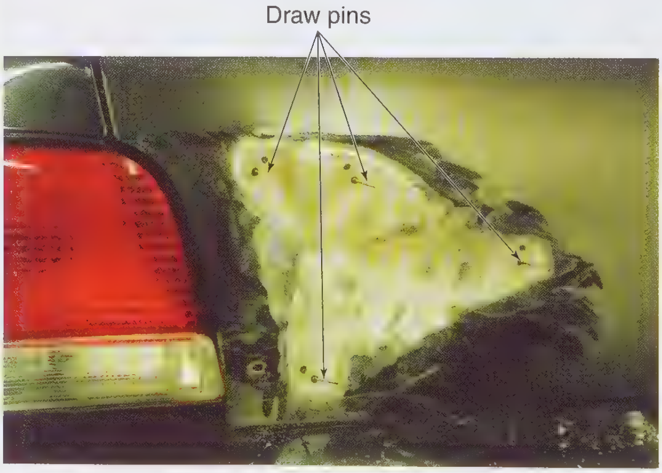


Figure 8-47. *This damage has several arrowheads. Draw pins are welded at the low areas of each arrowhead.*

dinging hammer. Use a gradual approach. Start at the bottom of the arrowhead and work upward. Alternate tapping from one side of the arrowhead to the other.

3. Raising—As the arrowheads are pulled out, weld additional pins in any remaining low areas. Raise these areas gradually, starting with the lowest pin and ending with the highest. Pull each pin slightly in an effort to gradually restore the crown in the panel. Remove the pins and check the damaged area for level.
4. Leveling—Any remaining high areas should be lowered by tapping. Tapping on high areas without supporting adjacent low or properly contoured areas may cause the crown to collapse. Weld draw pins in place to support adjacent low or properly contoured areas. While holding a draw pin to support the panel, tap any high areas with a dinging hammer.
5. Shrinking—Any metal that was pulled too high by a draw pin can be lowered by shrinking with the draw pin welder. Heat the area with the welding tip, tap the heated area twice, and then cool the area with a wet rag.

One-Sided Repair, Body Line

The steps in performing a one-sided arrowhead repair that involves a body line are as follows:

1. Raising—Weld a line of draw pins to the damaged body line. If a gang clamp is available, hook it up to the draw pins. Partially raise the body line. If a gang clamp is not available, use the slide hammer to raise the body line, starting with the lowest pin and ending with the highest. After partially raising the body line, weld a draw pin below the point of the arrowhead. Use a slide hammer to pull the pin out.

NOTE

A W-shaped wire can be used in place of draw pins to raise the body line. If W-shaped wire is used, pull it with a claw handle. See Figure 8-48.

2. Leveling—While pulling out on the pin below the point of the arrowhead, use a dinging hammer to lower the sides of the arrowhead. Work from the outermost parts of the arrowhead's sides toward the point.
3. Raising—Return to the draw pins in the body line. Raise them to the proper height. Set draw pins in the shaft of the arrowhead. Raise these low areas by starting at the ends and working toward the center.
4. Shrinking—Any metal that was pulled too high by a draw pin can be lowered by shrinking with the draw pin welder. Heat the area with the welding tip, tap the heated area twice, and then cool the area with a wet rag.

Two-Sided Repair, No Body Line

A two-sided arrowhead repair that does not involve a body line is relatively simple. The high-crown panel is stiff enough to be metal finished, but it may also be roughed out and filled. If a change in panel length is present, begin with step 1 below. If the panel length is correct, begin with step 2. The steps in performing this type of repair are as follows:

1. Pushing—Use a four-ton hydraulic power set to restore the length of the panel. As the panel lengthens, the lift reaction will raise the low area.
2. Raising—Use a dolly with the same contour as the underside of the undamaged panel to hit just under the point of each arrowhead. Start with the deepest arrowhead and gradually raise each. Continue tapping with the dolly until each arrowhead is raised.
3. Leveling—Hold the dolly tightly against the area under the point. Use a dinging hammer to lower the high ridges on the side of each arrowhead. Start at the bottom of the arrowhead and work toward the point. Alternate sides when hammering toward the point. The leveling releases the arrowhead.
4. Stretching—If the arrowhead has a sharp point that was not removed by hammer-off-dolly tapping, use hammer-on-dolly technique to stretch the upset metal. Press a dolly with the same contour as the underside of the undamaged panel against the inside of the panel, under the point of the arrowhead. Tap on the point with a stretching hammer. Start with light taps. If the metal does not stretch, tap harder. Use the dolly to raise the low areas that remain once the arrowheads have been released. Tap out on the underside of the panel with the dolly. If an upset area—a V-shaped groove in the shaft—remains, it can be removed by hammer-on-dolly stretching. Start hammering on the dolly at one end of the V-groove and work toward the other end. See **Figure 8-49**.

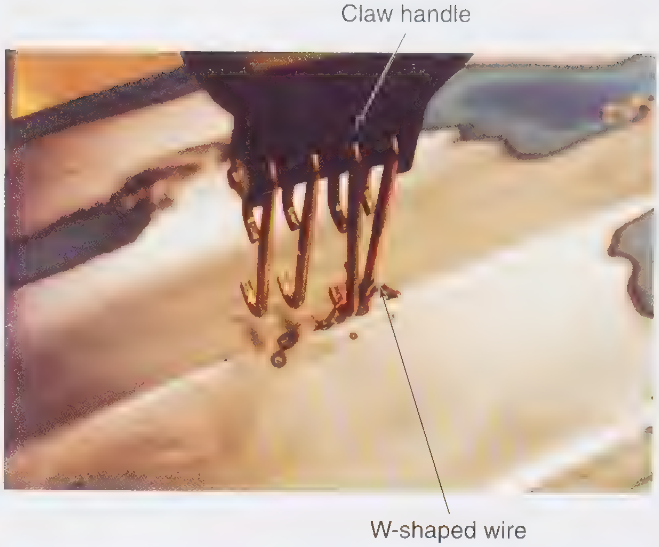


Figure 8-48. *When performing a one-sided arrowhead repair that involves a body line, raise the body line first. Here, W-shaped wire has been welded to the body line and a claw hook is attached to the wire to pull the damage out.*

5. Picking and filing—File across the damage. Any shiny spots indicate high areas. Tap the high areas down with a pick hammer. Areas not touched by the file are low areas; raise them by blind picking. Continue picking and filing until the repair area is smooth.

Two-Sided Repair, Body Line

Before beginning a two-sided arrowhead repair that involves a body line, determine which damage is stronger, the arrowhead or the body line. The strongest area is the deepest or has the most buckles. Start on the strongest area first. Most of the time it will be the body line.

1. Raising—Use a body chisel against the back side of the panel to partially raise the body line. It may take considerable force to get the body line to move. After raising the body line, use a dolly with the same contour as the underside of the undamaged panel to hit the underside of the panel below the point of the arrowhead. Continue to hit the panel until the buckle begins to unfold.
2. Leveling—While pushing out with the dolly under the point of the arrowhead, use a dinging hammer on the sides of the arrowhead. This hammer-off-dolly operation will lower the ridges and raise the point. Start hammering away from the point, alternating sides while working toward the point.
3. Raising—Use the body chisel to complete the raising of the body line.
4. Stretching—Use a dolly to bring up the shaft portion of the arrowhead. Then use a stretching hammer to correct the upset, starting at the point of the arrowhead. Hold the dolly tightly against the underside of the panel as the stretching hammer is used on the dolly. The stretching starts at both ends of the shaft and progresses toward the middle.
5. Filing—File across the damaged area. Low spots are areas that the file does not touch. Raise them by blind picking. High spots can be felt as resistance when filing or seen as shiny spots after filing. Tap down high spots with a pick hammer.

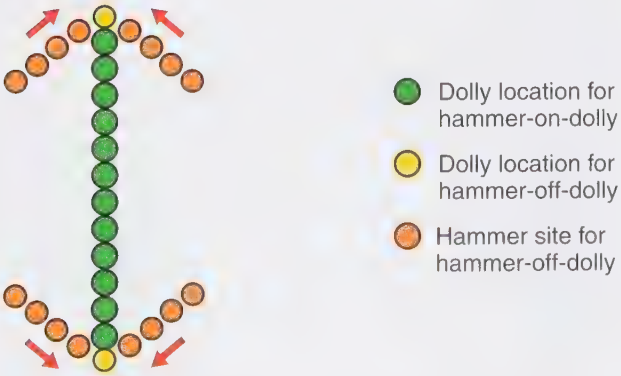

Dolly location for hammer-on-dolly
Dolly location for hammer-off-dolly
Hammer site for hammer-off-dolly

Figure 8-49. *This diagram shows how to stretch a V-groove.*

CAUTION

Never file on the body line. Filing on a sharp corner may cut through it.

Folds

Folds are caused by longitudinal force and are corrected by lengthening the panel. This type of damage can be remarkably easy to repair if you understand how it was created. To make this repair, use corrective force that is the opposite the force that created the damage.

Fold Repair, No Brace

In this type of repair, panel length is restored as the folds (buckles) are removed. If a body line is present, it is repaired along with the folds. The following example explains how to repair a damaged quarter panel, as it is the panel most likely to be repaired in this way.

1. Pushing—Set up a four-ton hydraulic power set inside the trunk. The base should be set against the wheelhouse and the pushing end should be located at the direct damage. As the ram is extended, the panel will lengthen and the damage will walk out.
2. Leveling—As the power set lengthens the panel, you must work the folds. Relieve the folds furthest from the point of impact first. The low areas are raised and the high areas are lowered by the hammer-off-dolly process. Gradually increase panel length as the folds are removed.
3. Stretching—Tight folds (where the folds touch), such as those shown in **Figure 8-50,** are upset. Hammer-on-dolly work will increase the surface area.
4. Filing—File across the repair area to identify high areas and low areas. Avoid any body lines. Pick and file to restore panel contour.

Fold Repair, Internal Brace

When making this type of repair, it is important to note that the internal brace is the strongest part of the damage. The length of the brace must be restored while repairing the folds. As the brace is lengthened, much of the damage in the folds will snap out. In the example that follows, the internal brace is a collapsed unirail. The panel does not have any direct damage. The folds are gentle, so minimal upset is present.

1. Pulling—Mount the vehicle on a frame machine and tie it down. Attach a clamp to the damaged frame rail and begin to pull out the damage. As the pull on the frame rail begins to restore panel length, the folds begin to move. High areas drop and low areas rise. See **Figure 8-51**.
2. Leveling—Hammer-off-dolly work will help unlock the folds as the panel length increases.
3. Stretching—Tight folds are upset. Stretch by hammering on the dolly after the panel length is restored.

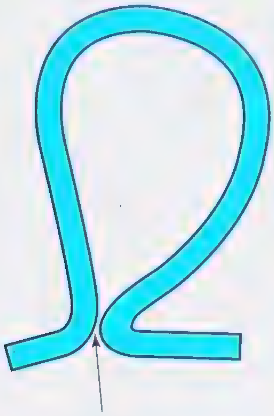


Figure 8-50. *In a tight fold, the folds touch. Stretching is necessary when repairing these types of folds.*

4. Filing—File across the repair area to identify high areas and low areas. Avoid body lines. Pick and file to restore panel contour.

Finishing

As previously mentioned, roughing out restores the approximate contour of a panel and finishing completes the repair by restoring the exact contour. The roughing out process must be completed before attempting finishing. Any remaining buckles and stretched or upset areas will cause problems during the finishing process. There are two ways to finish a panel: metal finishing and filling. Metal finishing means the lows and highs will be removed entirely by picking and filing after the roughing process is complete. In filling, body filler is applied to low areas and block sanded to restore the exact shape of the panel.

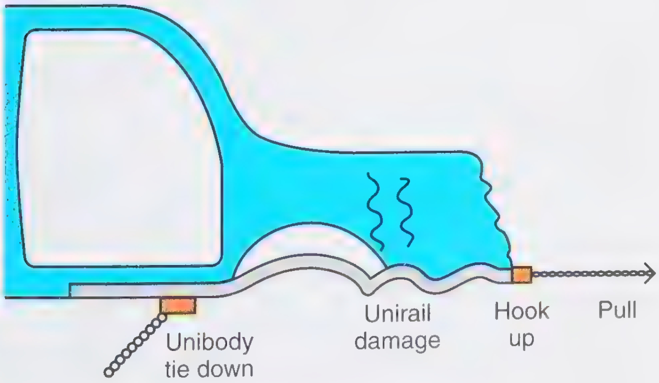


Figure 8-51. *Much of the indirect damage on this quarter panel will be pulled out when the frame rail is lengthened.*

Metal Finishing

Metal finishing is the continuation of the pick and file process started during roughing. If metal finishing is done correctly, no filler will be used in the repair.

To metal finish a panel, both sides of the panel must be accessible. Metal finishing is most successful on arrowheads in high-crown or double-crown panels without a body line. The arrowheads can be roughed out and the contour restored by metal finishing because the high-crown or double-crown panels are stiff enough to be easily worked. Additionally, high-crown panels are less likely to stretch than low-crown panels. Filler is a better choice for low crown and panels with body lines.

During the metal finishing process, every high area must be tapped down and every low area must be tapped up. Continue picking and filing until the panel is smooth and level. Identify high or low areas with a metal file or a grinder. The metal file or grinder disk contacts and marks high areas; low areas are not contacted by the file or grinder disk. Use short file strokes on double-crown panels. You can also check for highs and lows with a straightedge or with your hand. If you find a low area that is 1/8" in diameter or smaller, tap the area up with careful blind picking. One well-placed tap should be all that is required. Try not to raise the low area too much. File or grind to eliminate high areas that are 1/8" in diameter or smaller. Low or high areas that are larger than 1/8" in diameter should be moved with a series of light taps around the perimeter that gradually work toward the center.

When lowering a high area, do not cause the adjacent metal to collapse by tapping too hard. Support adjacent areas with a dolly. As the metal is worked, the picking will tighten the metal, making it less likely to move. Try to lower the panel to the proper contour rather than tapping a high area down and making a low spot. You must then tap the low area up. Too much tapping up and down will harden the panel, making it unworkable.

Filling

Filling involves the use of filler to restore panel contour once roughing out is completed. There are two types of filler used on vehicles: body filler and lead filler. Body filler, or plastic filler, is far more common than lead filler. Body filler requires less skill to apply than lead filler. When used properly, body filler is as durable as lead filler, except that lead filler will not crack as body filler does if a filled panel bends or flexes. Restoration shops and a few body shops still use lead filler.

Using Body Filler

Body filler should not be thicker than 1/8". Low spots deeper than 1/8" should be raised before filling. False stretch must be shrunk or eliminated. If a false stretch is popped in and filled, the "oil can" will eventually pop out and crack the filler. Cracked filler will allow moisture to reach the metal, causing rust.

NOTE

A panel that has been previously damaged and repaired may be damaged again. If the existing body filler is thicker than 1/8", it should be ground out and the low area should be raised. If the new fill area is adjacent to existing filler that is 1/8" thick or less, the new filler can be blended into the existing filler once the paint is removed from the existing filler. See Figure 8-52.

The first step in filling is to closely examine the repair area. The goal is to apply filler in a single application. Therefore, high spots must be eliminated before filling. Look for any high spots in the metal. Use a straightedge to locate highs. If highs are found, tap them down with a pick hammer.

Next, remove the paint from the fill area and 1" (25.4 mm) beyond the fill area. A grinder with a 24-grit disk may be used to remove the paint on high-crown steel panels. Grinding will leave deep scratches in the metal. The filler will anchor in the scratches. This is called ***mechanical adhesion***. Because the heat produced by grinding can cause panel warping, use only 80-grit sandpaper on low-crown steel panels and all aluminum panels. The scratches created by sanding with 80-grit sandpaper will also anchor body filler by mechanical adhesion.

There are two acceptable surfaces that filler can be applied over—bare metal and epoxy primer. For corrosion protection, some manufacturers recommend that filler be applied over epoxy primer. If epoxy primer is to be used, remove the paint from the area to be filled. Mix the epoxy primer and spray on the recommended number of coats. After the epoxy primer has cured, it should be sanded with 320-grit sandpaper to provide scratches for mechanical adhesion of the body filler.

Once the panel surface is prepared, mix the filler according to the manufacturer's recommendations. Read the instructions on the can carefully. Mixing filler and hardener is a critical step in panel repair. Using the wrong amount of hardener will cause problems. The can of filler will list the proper mixing ratio.

Always use clean mixing sticks, paddles, and mixing boards. Dirty equipment can contaminate the newly mixed filler. The mixing board must have a nonabsorbent surface, such as metal or plastic. Never use cardboard as a mixing board. One type of mixing board is a tablet of nonabsorbent paper sheets. After a sheet is used for mixing, it is torn off the tablet, exposing the next clean sheet.

Before mixing filler, make sure it is uniform in consistency. If a bluish liquid, which is the resin in the filler, is visible inside the filler can, use a clean paint stick to mix the resin back into the filler.

Use a clean paint stick or paddle to remove the desired amount of filler from the can and place it on the mixing board. Put the lid back on the filler can as soon as possible. An open can of filler can be easily contaminated with the sanding dust present in the shop.

Paste-type hardener will separate inside the tube. Knead the tube of hardener to thoroughly mix the separated hardener. See **Figure 8-53**. Squeeze out the proper amount of hardener next to the filler on the mixing board, **Figure 8-54**. Use a clean paint stick or paddle to stir the hardener and filler together. Continue to stir until the filler is a uniform color, with no streaks of hardener or unmixed filler. The filler is now ready to be applied in the low area.

The curing of the mixed filler produces heat, which can be felt on the mixing board. The curing process begins as soon as hardener and filler are mixed. The mixed filler will stiffen as it cures and will only be spreadable for a few minutes. Therefore, it is important to apply

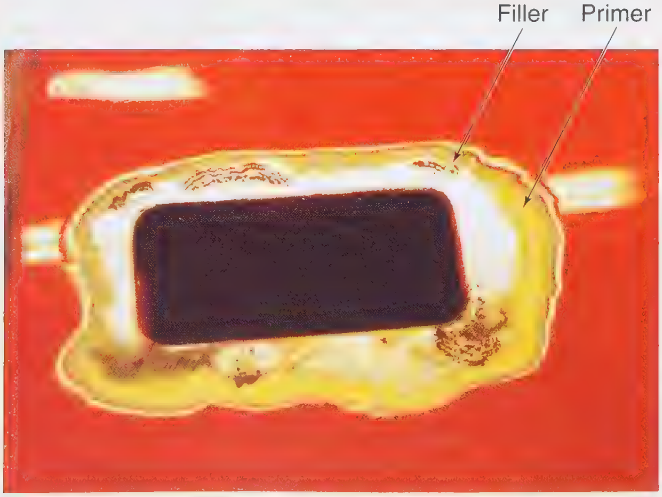


Figure 8-52. *This panel contains body filler that was applied during a previous repair.*

CREAM HARDENER

Figure 8-53. *Kneading the hardener tube will mix the hardener.*

the filler as soon as it is mixed. Once the mixed filler has cured too much, it is not workable.

CAUTION

Never return mixed filler to the can. The mixed filler will contaminate the unmixed filler.

Use a clean spreader to apply a thin coat of mixed filler to the low area. Press down hard on the filler as the first coat is applied. This will squeeze out the air from under the filler and reduce the number of pinholes. Pinholes are pockets or voids in cured filler. Apply additional coats of filler, building up the filler until an overfill (filler higher than the surrounding metal) is achieved. After overfilling the low area, use light strokes with the spreader on the filler to obtain a smooth surface. Stop working the filler when it begins to stiffen. Allow the filler to cure. Shop temperatures below 60°F increase cure time. Clean the mixing equipment while the filler is curing.

Filling a body line can be difficult. A simple body line can be filled by spreading an overfill on the peak of the body line. A complex body line can be repaired by forming the filler to match the contour of the undamaged body line. A contour sander can be used to mold the filler. Put 2" (50 mm) masking tape over the contour sander that best matches the shape of the original body line. Apply the mixed body filler to the damaged body line and press the body filler into the proper shape with the contour sander. Hold or tape the contour sander in place until the filler hardens. When the filler has hardened, remove the sander. The filler should be shaped so it requires little sanding.

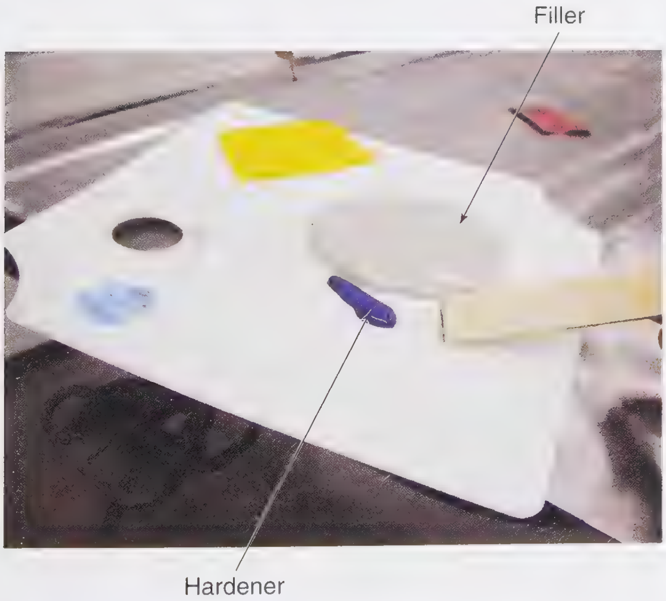


Figure 8-54. *Body filler and hardener are combined on a mixing board.*

Most problems are caused by the filler or hardener itself, the mixing procedure, or the condition of the application site. To avoid problems, follow these guidelines:

- Check the manufacturer's date on the filler can. If the filler is over one year old, do not use it. This rule applies even if the can is unopened.
- If runny liquid hardener comes out of the tube after kneading, do not use the hardener.
- If the metal is below 70°F, warm the metal with a heat lamp before applying the filler.
- If the metal is damp, use a heat lamp to warm and dry the metal before applying the filler.
- Follow the recommended mixing procedures. Too much hardener, which is evidenced by a deeply colored mixed filler, will cause pinholes and a lack of adhesion. Too little hardener will cause an insufficient cure (soft filler) and a lack of adhesion.
- If the filler is to be applied over bare metal, use a grinder or 80-grit sandpaper to remove the paint. This procedure will abrade the surface, allowing the filler to bind to the rough surface.
- Some manufacturers recommend that filler be applied over epoxy primer. The bare metal is sprayed with epoxy primer. Once the epoxy primer cures, it is scuffed and the filler is applied. Check the paint manufacturer's recommended cure time. It may be as long as 24 hours.
- The application site should be ground or sanded and then cleaned to remove oil, wax, or any other surface contamination.

The initial removal of excess filler is not really a sanding operation. When the filler has hardened to the consistency of processed cheese, a surform tool, commonly called a cheese grater, is dragged across the surface. The cheese grater, shown in **Figure 8-55**, works like a file to remove excess filler. Grating is a fast way to remove filler. It is faster than most sanding operations. However, do not grate the filler too soon. You must allow the filler to cure long enough to adhere to the metal. Grating too early will pull the filler off from around the edges of the repair. The ragged edges will require additional filler. If tack-free filler is used, grating is not required. Allowing the filler to harden completely and then sanding is an acceptable alternative.

Fully cured filler is sanded starting with 40-grit paper, followed by 80-grit paper and then 180-grit paper. On small areas that the sanding tool can span, start with 80-grit paper. Sanding before the filler is fully cured will clog the sandpaper with sticky filler residue. The filler can be tested for full cure by scratching it with a fingernail. If the filler feels soft, moist, or sticky, it is not ready for sanding. If the filler feels dry and hard, it is ready for sanding. The sanding process will level and featheredge the filler. Do not prime the filler for at least ninety minutes after it is applied. Solvents will evaporate from the filler even after it has cured. It takes ninety minutes for all the solvents to completely evaporate from the filler.

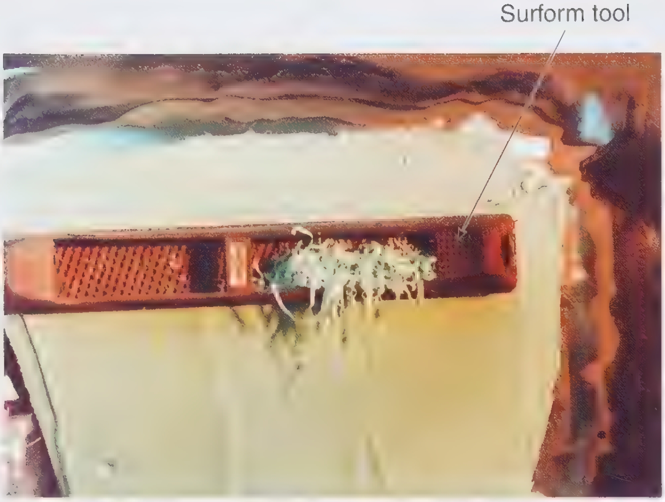


Figure 8-55. *A surform tool can be used to quickly remove excess filler.*

Block sanding can be done with hand or power tools. In either case, the sandpaper surface should span the filled area whenever possible. This allows the undamaged edges of the panel to support the sandpaper, preventing the paper from undercutting the filler. If the filled area is too large for the sandpaper to span, you must sand the filler as evenly as possible in separate sections. The 40-grit or 80-grit sandpaper used to sand body filler can easily scratch the paint of adjacent panels. Protect the paint on undamaged areas with masking tape and cardboard.

Block sanding levels filler. The goal is to apply one coat of filler and block sand it level. Too many technicians fill, block sand, find a high area, and tap it down. They then refill this area, block sand, find a low area, and refill again. Avoid wasteful refilling by identifying all high and low areas, applying an overfill of filler, and using proper block sanding techniques.

Block sanding can be one of the most difficult auto body repair skills to learn. A common problem is oversanding the body filler, causing an undercut. An undercut occurs when the filler has been sanded so much that it is lower than the surrounding metal. The undercut must be refilled and block sanded again. Sanding the filler to match the surrounding contour, such as double crown or a body line, is another potential problem.

First, consider a 6" (15 mm) diameter section of body filler. A sanding stick can span this amount of filler. Hand placement on the sanding stick is important. Hands should be placed at either end of the stick and they should be supported by the undamaged metal around the filler. The undamaged metal will serve as a guide for block sanding and will prevent undercutting. Always follow the crown on the panel when sanding. Block sanding low, medium, high, and double crown is shown in **Figure 8-56**. Hold the sanding stick flat on low or medium crown. See Figure 8-56A. On high crown, hold the sanding stick on edge as shown in Figure 8-56B. If the sanding stick is held flat, the high crown will be sanded flat. When sanding double crown, the stick must be bent to follow one of the crowns, Figure 8-56C. On small areas, start sanding with 80-grit sandpaper. When a featheredge appears around the filler, switch to 180-grit sandpaper to remove the 80-grit scratches and to extend the featheredge. If there are no problems with the filler, such as pinholes, the filler is ready for the undercoat. Some body shops apply a thin coat of premium body filler over the filler and sand that filler with 180-grit sandpaper followed with 320-grit sandpaper.

If pinholes or other low areas are present, they should be featheredged and filled with body filler. **Figure 8-57A** shows an edge that could not be featheredged because the area is still low. This area, as well as the low area that remains after block sanding, should be filled as shown in **Figure 8-57B**. Once the second application of filler has cured, sand it with 180-grit sandpaper. Sand on the new filler only, not the surrounding filler.

Areas larger than 6" (15 mm) in diameter can be initially sanded with 40-grit sandpaper on an air file as shown in **Figure 8-58**. The air file will level the filler much faster than hand sanding. Try to sand the entire area gradually and evenly. Sand until a featheredge is made all around the filler. Then switch to 80-grit sandpaper. At this point, use hand sanding rather than power sanding because hand sanding is easier to control. Large areas of filler can be sanded with a yardstick instead of a sanding stick. Because the yardstick is longer, it can span a wider area of filler. It is also flexible, so it can be bent to conform to a medium crown. After removing the 40-grit scratches with 80-grit paper, switch to 180-grit sandpaper to remove the 80-grit scratches. To sand a crowned area around a wheel opening, use the curved surface of the sanding block as shown in **Figure 8-59**.

Sanding a body line in filler is challenging. It can be difficult to sand a straight line that matches the undamaged contour of the body line. Any deviation will be easily visible in the repaired vehicle. One way to form a body line out of body filler is to use a body line sander, such as the one shown in **Figure 8-60**.

A conformable sander is another tool that can shape body filler. The conformable sander is pressed into an undamaged portion of the body line. The thin plastic sheets take on the contour of the body line. The sandpaper must be carefully applied to the contour of the sander. A roller tool is used to make sure that the sandpaper matches the contour of the sander exactly. The guide is positioned so the sander can cut the body line in the filler. It is held to the vehicle with suction cups.

NOTE

The guide's suction cups will adhere only to painted surfaces.

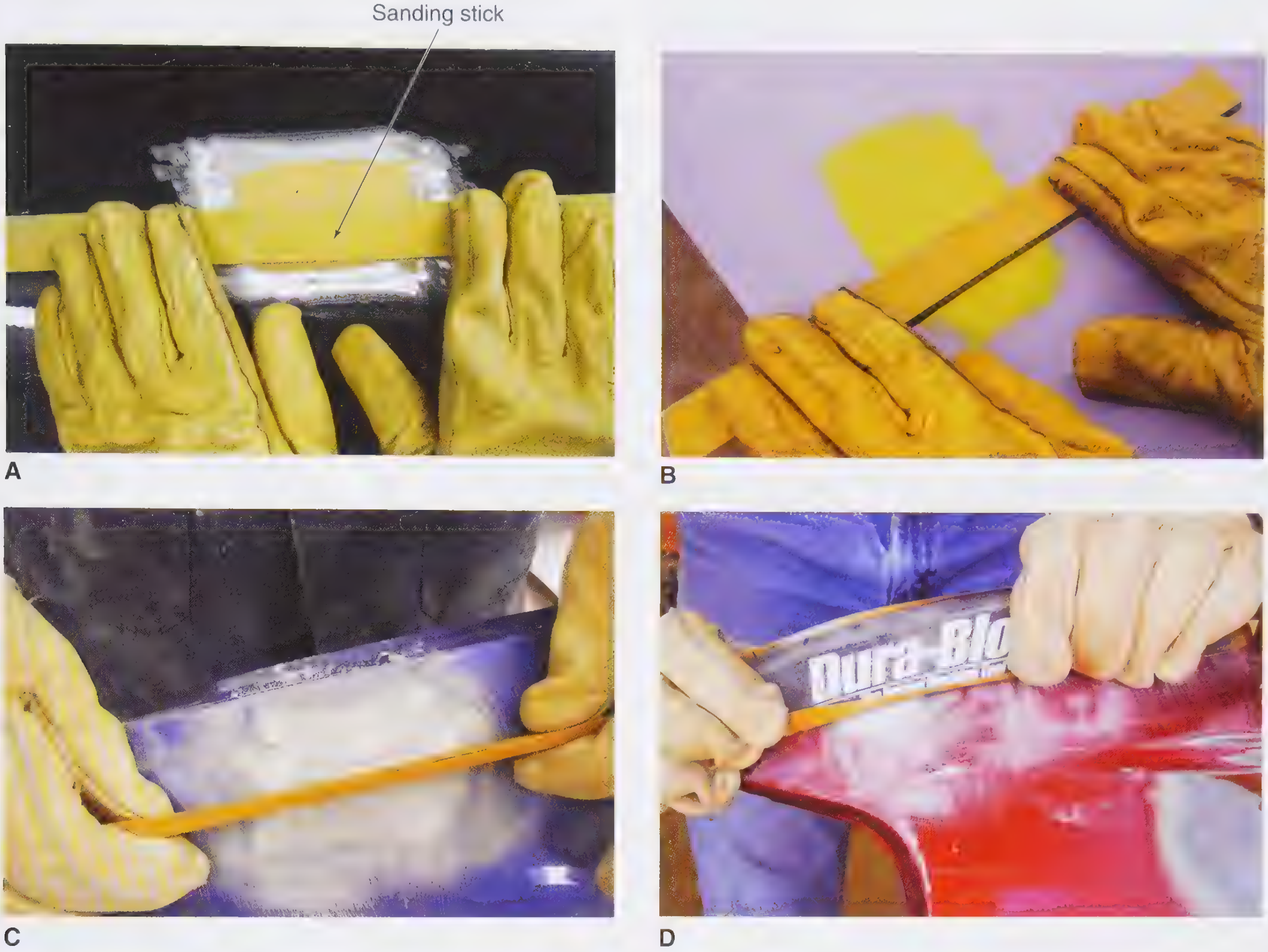


Figure 8-56. *A—Use the undamaged metal around the filler as a guide when sanding low crown. B—Position the sanding stick flat to sand medium crown. The body filler has been applied over epoxy primer. C—Hold the sanding stick on edge to sand high crown. D—Bend the sanding stick to sand double crown.*

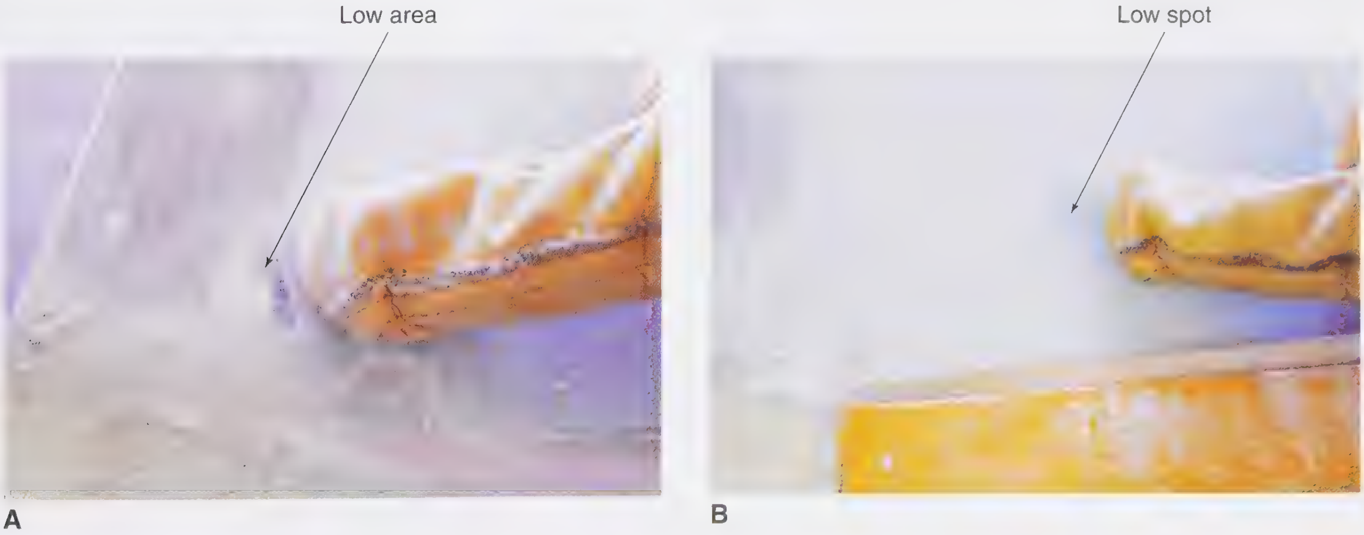


Figure 8-57. *A—A low spot prevented featheredging in this area of body filler. B—This area is low after block sanding.*

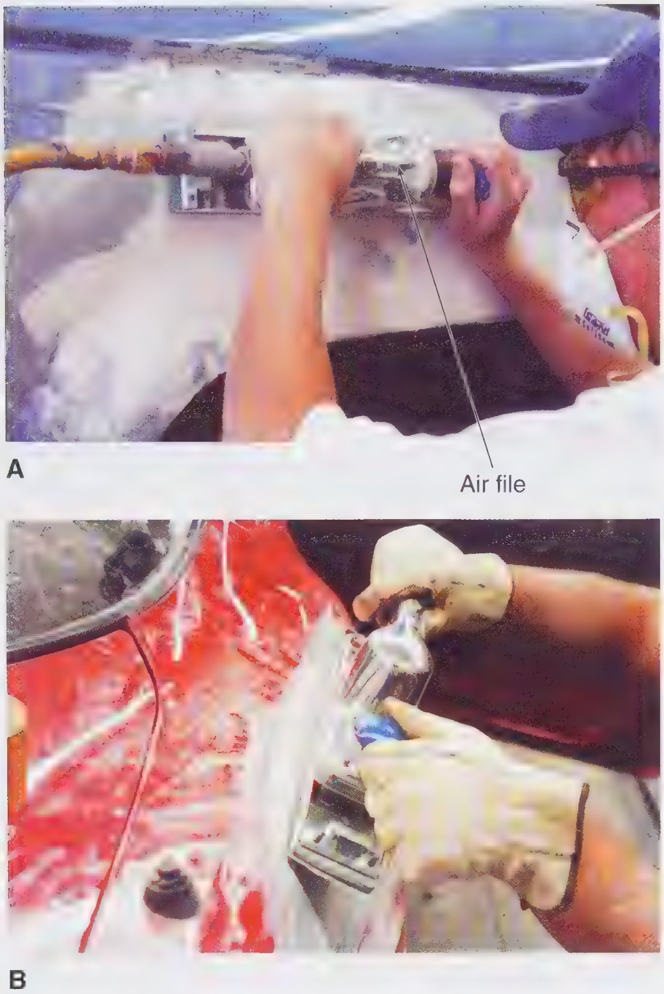


Figure 8-58. *A—The air file should span the filler and be moved up and down. B—Using the edge of the air file will prevent the file from flattening the crown.*

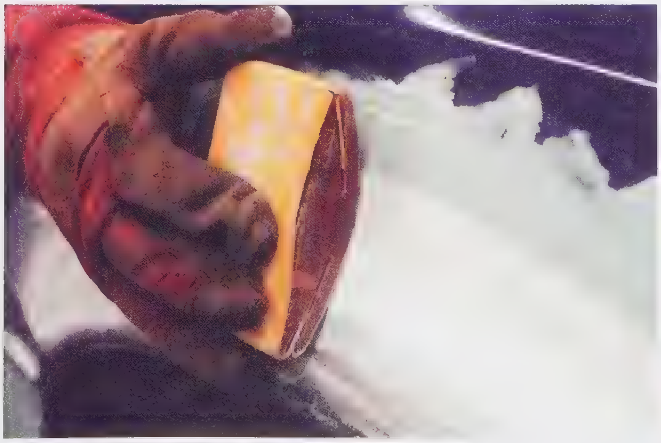


Figure 8-59. *Attaching the sandpaper to the curved side of the block allows the block to be used to sand filler on a concave surface.*

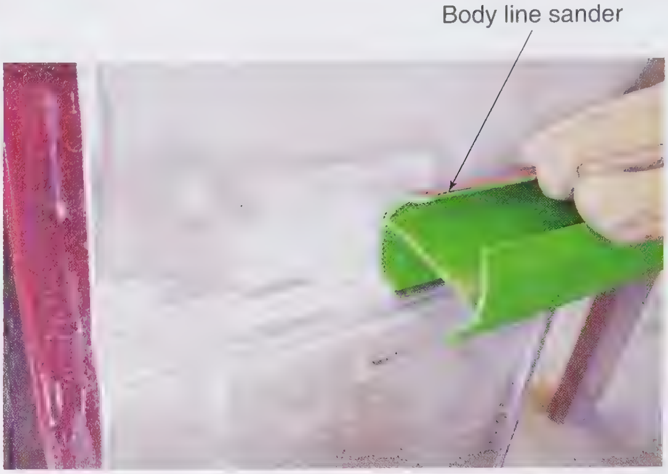


Figure 8-60. *This sanding tool is moved along the body filler to shape the body line.*

The conformable sander is then placed on the guide and is moved back and forth to shape the body line. The last of the filler is sanded from the body line by raising the outer plastic sheets from one end to the sander. This will allow the sander to reach slightly deeper into the body line and sand out the very bottom of the body line. **Figure 8-61** shows a contour sander in use. This particular sander has different surfaces to match the contours of various body lines.

One common problem when using filler is the presence of pinholes. Pinholes are air pockets in the cured filler. **Figure 8-62** shows pinholes. Blowing a stream of compressed air over the cured and sanded filler can reveal this problem. The air will blow out sanding dust from the pinholes. Pinholes can be corrected with an application of putty. To minimize sanding, use a razor blade to apply the putty. The sharp edge of the razor blade will fill the pinhole with putty and remove the excess. After

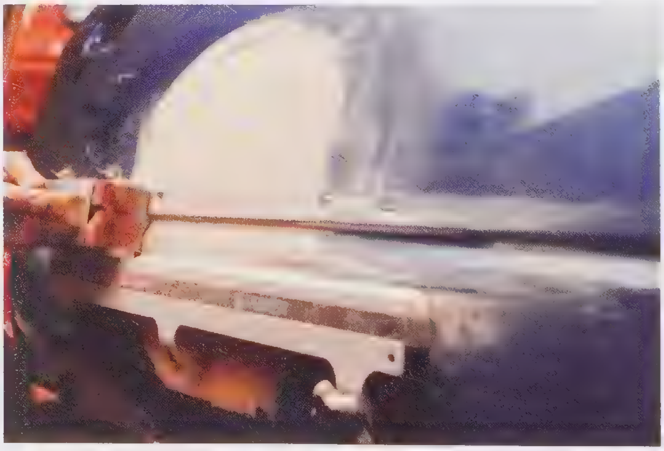


Figure 8-61. *The conformable sander will easily reshape a body line.*

the putty has cured, the filler is sanded with 180-grit sandpaper. To prevent problems, use high-quality filler. Mix it properly and observe the recommended cure times.

Using Lead Filler

Lead filler was commonly used to repair dents in vehicles before the invention of body filler. It still has a place in body repair. Some technicians use lead filler on a repaired panel edge, such as the edge of a quarter panel adjacent to a door. The lead filler is less likely to chip off if the panel edge is hit. Lead filler is supplied in sticks. The sticks have a lead/tin ratio of 70/30 or 60/40. The 70/30 sticks are more expensive, but they are easier to apply.

The key to applying lead is learning to control the heat used to soften the lead stick. Lead that is heated too much will melt and run off the panel, rendering it useless. Heat the lead stick just enough to soften it, but not enough to melt it. The lead stick will change from a dull silver color to a bright and shiny silver as it melts. Avoid heating the lead stick to the shiny stage. As with body filler, do not try to fill areas deeper than 1/8" with lead, as this simply saves on the cost of materials. Lead filler application is easier on a horizontal surface than a vertical surface. On a vertical surface, gravity is constantly trying to pull the softened lead filler down and out of the fill area.

WARNING

Lead is a toxic substance. Wear gloves when handling lead products. When melting lead, work in a well-ventilated area and wear approved respiratory protective equipment to prevent inhalation of lead dust or vapors. Wash your hands thoroughly after handling lead or working in a lead-contaminated area.

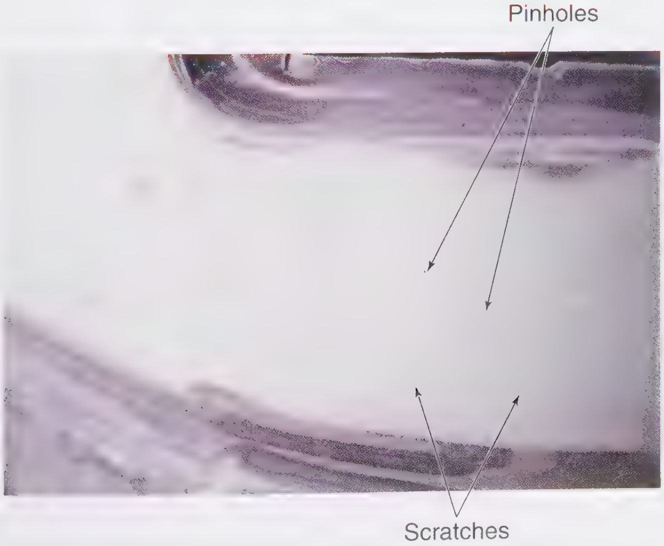


Figure 8-62. *This cured body filler has numerous pinholes and scratches.*

There are five distinct steps in lead filler application:

- Stripping.
- Tinning.
- Heating.
- Applying.
- Smoothing.

Refer to **Figure 8-63** as you read through the following explanation.

To begin the lead filling process, remove the paint from the panel surrounding the area to be filled. The paint must be removed from the entire area to be heated. An area at least 5-6 times the size of the fill area will be heated.

The fill area must be prepared before the lead is applied. This process is called tinning. During tinning, a liquid flux is applied to the fill area. The flux cleans the bare metal and prepares it for the application of lead. Figure 8-63A shows a brush being used to apply flux to a small fill area. After the flux is applied, the fill area and the entire bare metal area are gradually heated. A propane torch or an oxyacetylene torch with a special tip that burns only acetylene must be used to heat the metal. The metal is heated enough that the lead stick softens and adheres to the panel when touched to the heated metal. See Figure 8-63B. If the metal is too hot, the lead will melt and run off the panel. Use steel wool or a rag to wipe the excess lead off the fill area.

After tinning the repair area, the filler can be applied. Two things must happen during the application step. The bare metal and fill areas must be kept hot, but not hot enough to melt off the lead in the tinned area. At the same time, the lead stick must be heated enough to soften it. Hold the torch at an angle so it can heat both the lead stick and the fill area as the lead is applied to the panel. Lay out enough softened lead to overfill the fill area, Figure 8-63C.

After applying the lead, the repair must be smoothed. During this step, the lead filler on the panel is softened with heat. The softened lead filler is then spread out and smoothed with a wooden paddle. See Figure 8-63D. The face of the paddle is coated with a layer of tallow or paddle lubricant to prevent the lead from sticking to the paddle. To coat the paddle with tallow, heat the face of the paddle with the torch and touch the face of the paddle to the surface of the tallow. The hot paddle face will melt the tallow.

Once the lead filler cools, it can be filed in the same way as filing high areas when metal finishing. The lead can be finished by block sanding in the same way as body filler. Reapplication of lead filler is not recommended because the existing lead on the panel will need to be heated and may melt off unless extreme care is taken. Lead filler can be covered with body filler, if needed.

WARNING

The lead dust created when filing and sanding can be hazardous to your health. Always wear an approved respirator when working with lead products.

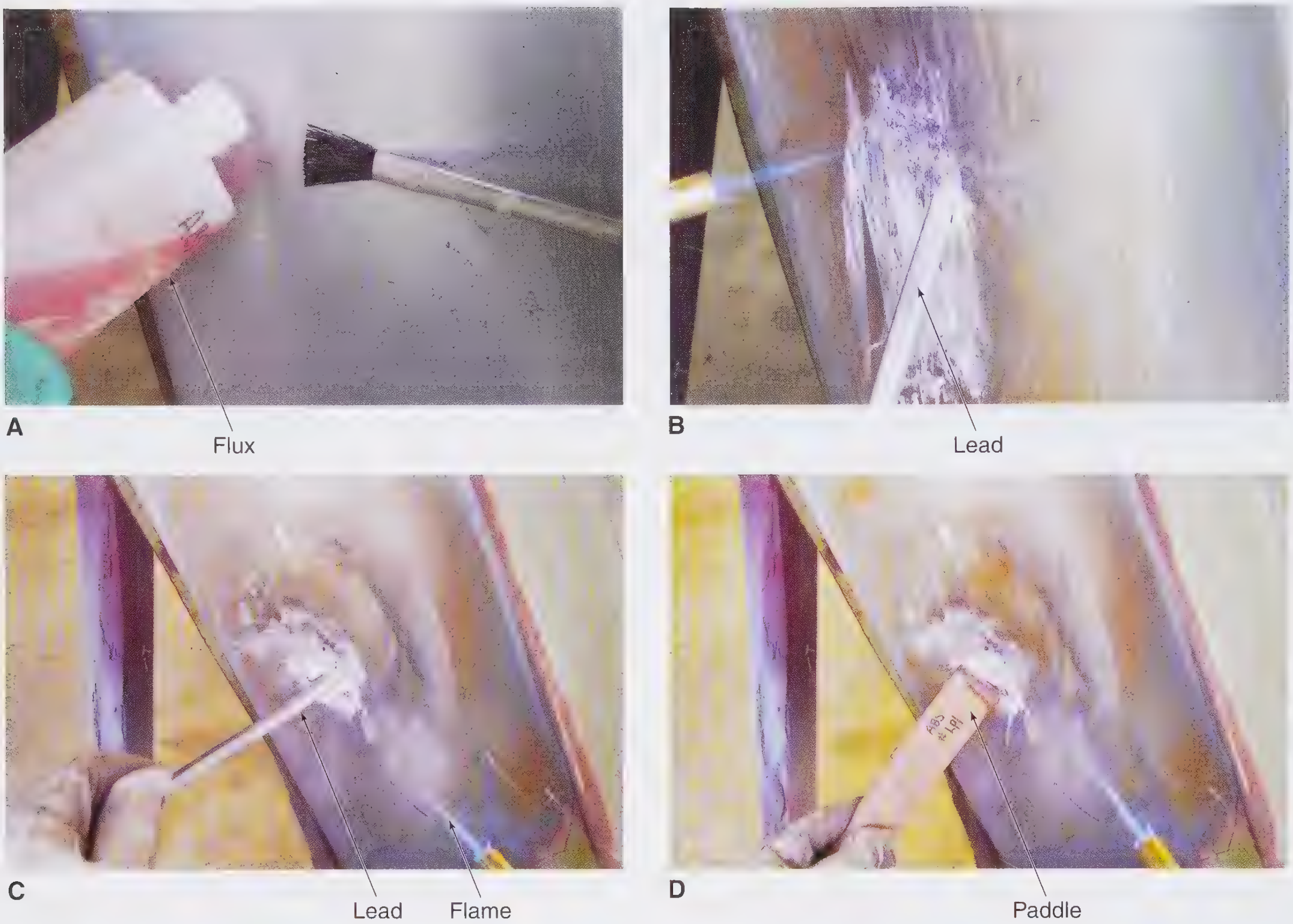


Figure 8-63. *Lead is still used as filler in some shops. A—The flux is spread with a brush. B—The heat from the panel should soften the lead. C—Softened lead is applied to the fill area. Notice the distance between the flame and the lead. D—A wooden paddle is used to smooth the softened lead.*

Aluminum Panel Repair Operations

Aluminum panels, such as deck lids and hoods, are installed on some vehicles. Aluminum is lighter than steel. Additionally, aluminum is easier to recycle than steel. It is anticipated that the use of aluminum body panels will increase in the future.

Aluminum panels found on vehicles are usually low-crown, bolted panels. Dents are the most common type of damage that occurs on these panels. When repairing a dent in a low-crown panel, care must be taken to prevent stretching the panel. Aluminum is softer than steel. Therefore, hammer-on-dolly straightening will easily stretch aluminum. Do not use hammer-on-dolly techniques when straightening aluminum.

Steel particles left over on grinder disks, sandpaper, and files will contaminate bare aluminum. Use a new disk or new sandpaper when working on an aluminum panel. Also, dedicate a body file (eight teeth per inch) for use on aluminum. Aluminum can be easily gouged by a file. Grind the edges of the file so they will not dig into the metal.

Aluminum is much more sensitive to heat than steel. To prevent warpage, power sanders used on aluminum panels should be equipped with a foam backing pad. The use of 80-grit (or finer) sandpaper and disks will prevent excessive removal of aluminum while sanding. Aluminum does not change color when heated as steel does. Controlled heat is very beneficial in repairing aluminum. Stretched aluminum can be shrunk with a butane-powered micro-torch. The technique is similar to that used for steel. Remove the paint from the panel before heating the damaged area with the micro-torch.

When performing shrinking, leveling, or raising operations on an aluminum panel, the hammer blows must be softer than those used on steel. Tap lightly. The faces of hammers and dollies used for aluminum repair must be free from nicks and gouges. Any irregularities on the faces of the straightening tools will be transferred to the aluminum. Some technicians use plastic- or rawhide-faced hammers to straighten aluminum. Most body fillers used on steel can also be used on aluminum. The aluminum panel should be coated with epoxy primer before applying the filler.

Summary

- Displaced metal is undamaged but held out of position by the arrowhead buckles.
- The grains in the metal are too small to be seen, but their arrangement determines the shape of the metal.
- A force greater than the yield point will rearrange the grain set, causing buckles and changing the shape of the panel.
- A stretch means that the grains have been thinned, flattened, and elongated.
- An upset means that the grains have been shortened, thickened, and bunched together.
- Only after you carefully examine and analyze the damage will you be able to decide if the damaged part should be repaired or replaced.
- Easily replaced, low-cost panels, such as fenders and door skins, are often replaced if they have more than minor damage.
- To repair panel damage caused by longitudinal force, the panel's length must be restored.
- To repair damage caused by lateral force, not only must the length be restored but the surface area may also have to be changed.
- Before you can begin the repair of a damaged panel, various components must be removed from the vehicle to allow access to the damage.
- Roughing out restores the damaged panel to its approximate contour, and finishing completes the repair by restoring the exact contour of the panel.
- When metal is upset, its surface area is reduced and its thickness is increased. Stretching restores the metal to its correct dimensions.
- A false stretch is a bulge that pops in when pressed and out when released.
- Shrinking reduces the surface area of stretched metal.
- Uncontrolled use of heat on a low-crown panel will cause warp damage.
- Kinking involves the use of a shrinking hammer (serrated-faced hammer) or a sharp pick hammer to reduce the surface area by gathering the metal together.
- Chasing the dent occurs because the low-crown metal is floppy and is easily pushed in.
- Picking raises small lows and lowers small highs.
- Filing is used to identify high areas and low areas.
- In a one-sided repair, only the outside of the panel is worked. This type of repair is performed when the damaged panel is boxed or if accessing the back side of the panel is difficult.
- In a two-sided repair, both sides of the panel are worked. Access to the back side of the panel is required in a two-sided repair.
- Metal finishing is the continuation of the pick and file process started during roughing. If metal finishing is done correctly, no filler will be used in the repair.
- Filling involves the use of filler to restore panel contour once roughing out is completed.
- When performing shrinking, leveling, or raising operations on an aluminum panel, the hammer blows must be softer than those used on steel.

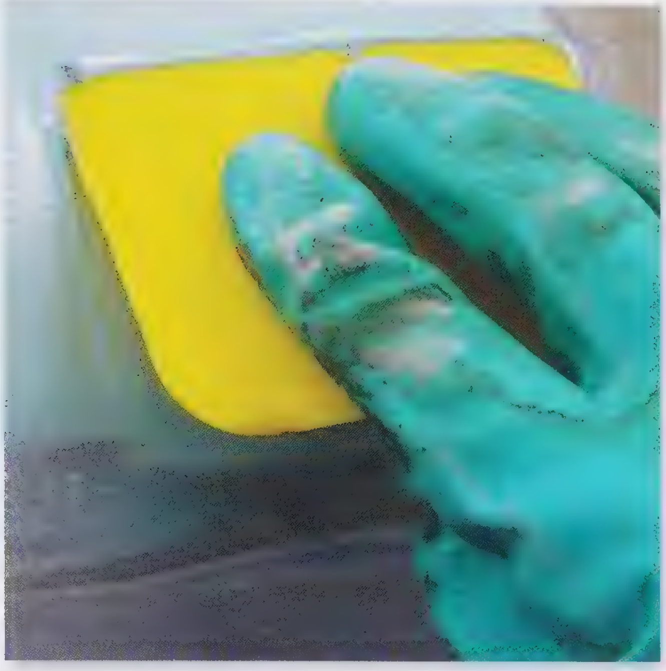
Review Questions

Please do not write in this textbook. Place your answers on a separate sheet of paper.

1. The damage repair sequence involves analyzing the damage, planning the repair, accessing the damage, ______, and finishing.
2. A bend of reflected light on a panel indicates a(n) ______ in the panel's surface.
3. A straightedge can be used to locate dents in panels that are ______ in only one direction.
4. A damaged panel is replaced if the cost of repair is at least ______% of the cost of replacement.
5. ______ will loosen the screws holding a steel wheel opening molding in place.
6. Explain the lift reaction.
7. When pulling on a plate, the pull should be perpendicular to the plate. True or False?
8. When using a hydraulic ram to lengthen a panel, which should be stronger, the damage or the base?
9. Hammering on the dolly causes the metal to ______.
10. Explain how to heat shrink a high, stretched area.
11. A(n) ______ is used to tighten floppy metal prior to filling.
12. Pick and filing should be done at the beginning of the repair sequence. True or False?
13. A damaged internal brace is replaced last. True or False?
14. Filler can be applied over ______ metal or ______ primer.
15. The correct sequence of sandpaper grits to use when sanding a 12" (30 mm) diameter section of filler is ______, ______, and ______.

ASE-Type Questions

1. Technician A says that a lateral force acting on a high-crown panel causes arrowheads. Technician B says that an upset is an increase in the surface area of a panel. Who is right?
   (A) A only.
   (B) B only.
   (C) Both A and B.
   (D) Neither A nor B.
2. A damaged vehicle is being analyzed by two technicians. Technician A says that any damaged internal braces must be identified. Technician B says that any change in surface area must be identified. Who is right?
   (A) A only.
   (B) B only.
   (C) Both A and B.
   (D) Neither A nor B.
3. Planning includes which of the following?
   (A) Deciding what tools are needed.
   (B) Determining how to access the back side of a panel.
   (C) Identifying obstructions.
   (D) All of the above.
4. Plastic fender liners are held in place by which of the following?
   (A) Plastic rivets.
   (B) Bolts.
   (C) Welds.
   (D) Both A and B.
5. Technician A says a longitudinal force can shorten a panel's overall length. Technician B says a lateral force can also shorten a panel. Who is right?
   (A) A only.
   (B) B only.
   (C) Both A and B.
   (D) Neither A nor B.
6. Pushing with a 4-ton body jack provides what type of corrective force?
   (A) Shock.
   (B) Longitudinal.
   (C) Tension.
   (D) Lateral.
7. When stretching upset metal, Technician A says that the dolly should match the shape of the undamaged panel. Technician B says that the upset area is hit hammer-off-dolly. Who is right?
   (A) A only.
   (B) B only.
   (C) Both A and B.
   (D) Neither A nor B.
8. False stretch is corrected by ______.
   (A) shrinking
   (B) tapping on the nearest body line
   (C) removing an adjacent upset
   (D) All of the above.
9. Leveling is used to ______.
   (A) raise high areas, lower low areas
   (B) raise low areas, lower high areas
   (C) stretch metal
   (D) shrink metal
10. A low spot is raised with a draw pin. Technician A says the raised spot will be work hardened. Technician B says the raised spot will be softer than the surrounding metal. Who is right?
    (A) A only.
    (B) B only.
    (C) Both A and B.
    (D) Neither A nor B.
11. A damaged body line can be raised with a ______.
    (A) gang clamp and draw pins
    (B) body chisel
    (C) body jack and angle iron
    (D) All of the above.
12. All of the following can be used to shrink metal except a(n) ______.
    (A) draw pin welder
    (B) oxyacetylene torch
    (C) shrinking hammer
    (D) pull plate
13. Shrinking stretched metal with an oxyacetylene torch requires what size of tip?
    (A) #1.
    (B) #3.
    (C) #5.
    (D) #7.
14. When heat shrinking, the metal should be heated to what color?
    (A) White.
    (B) Orange.
    (C) Red.
    (D) Yellow.
15. A low area is to be filled. Technician A says the low area should be ground to the bare metal before filler is applied. Technician B says the low area should be ground to bare metal and then sprayed with epoxy primer before filler is applied. Who is right?
    (A) A only.
    (B) B only.
    (C) Both A and B.
    (D) Neither A nor B.



Chapter 9

Bolted Nonstructural Part Replacement

Objectives

After studying this chapter, you will be able to:

- Identify part sources.
- Apply basic skills used in bolted part replacement.
- Identify parts of bolted panel assemblies.
- Explain how to remove damaged bolted parts.
- Explain how to install and align bolted parts.

Technical Terms

aftermarket
appearance panel
bumper cover
crash beam
door shell
door skin
face bar
flush
hood latch
header panel
impact absorber
impact bar
isolators
J-clip
J-nut
level
OEM parts
reinforced fender
skin fender
stops
striker
used parts

Introduction

This chapter explains how to remove and replace bolted parts. Bolted parts include bumpers, fenders, hoods, doors, and deck lids. The chapter begins by discussing the sources of replacement parts. After part sources are discussed, the basic steps in bolted part replacement are explained. Finally, the procedures for replacing specific bolted parts are detailed.

Part Sources

Replacement bolted parts can be obtained from three sources: original equipment manufacturers, salvaged vehicles, and aftermarket suppliers. The source used depends on availability, the age of the vehicle, and the customers' desires.

Availability is a key issue when deciding on a part source. Replacement parts must be obtained in a reasonable amount of time. A damaged vehicle may sit for days or weeks waiting for parts. This wait is inconvenient for the customer. The age of the vehicle is another factor in the choice of parts. An older vehicle, which is worth less money than a newer vehicle, is often repaired with the cheapest parts available. However, a customer may insist on high-quality parts to repair an older vehicle.

OEM Parts

The letters OEM stand for original equipment manufacturer. ***OEM parts*** are replacement parts made by the same company that made the parts installed on the vehicle when it was assembled. All replacement parts for late-model vehicles (10 years old or newer) are available as OEM parts. In rare cases, there may be a wait for OEM parts. This usually involves parts for a high-volume, currently produced model, because these parts are also needed for installation on vehicles at the factory. This also may be an issue on limited production vehicles, because there is little demand for these parts and they are not stocked.

OEM parts are obtained from a new car dealership. The dealership may or may not stock collision parts. If the parts are not in stock, the dealership can often order them from a central warehouse. Many times, the ordered parts will be delivered the next business day. However, some dealerships may only order collision parts once a week, resulting in a longer wait for the collision repair shop. Most shops cultivate a relationship with dealerships because the shop relies heavily on the dealership's ability to supply the required parts in a timely manner. **Figure 9-1** shows an OEM part and its packaging. Most OEM parts are warranted against corrosion resistance. These parts are sold individually, not as assemblies. Always check the replacement parts for damage before installation.

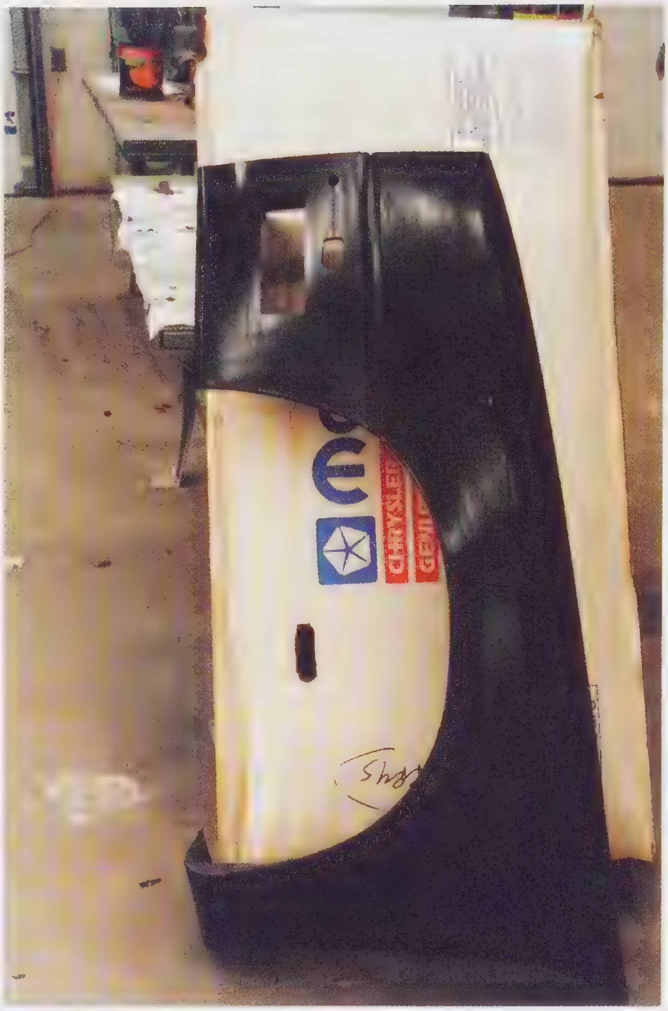


Figure 9-1. *This is an OEM fender and the box it is shipped in.*

Used Parts

Used parts, or recycled parts, are taken off salvaged vehicles. These parts are obtained from a salvage yard. Used parts are sold as part of an assembly. For example, **Figure 9-2** shows a used door assembly consisting of the door shell, hinges, glass, regulator, latch, lock, handle, and trim panel. A front clip is the entire front of the vehicle from the cowl forward. In some repairs, it is more economical to obtain all the bolted parts from a used front clip—fenders, hood, grille, headlights, and front bumper—than it is to order these individually as OEM parts.

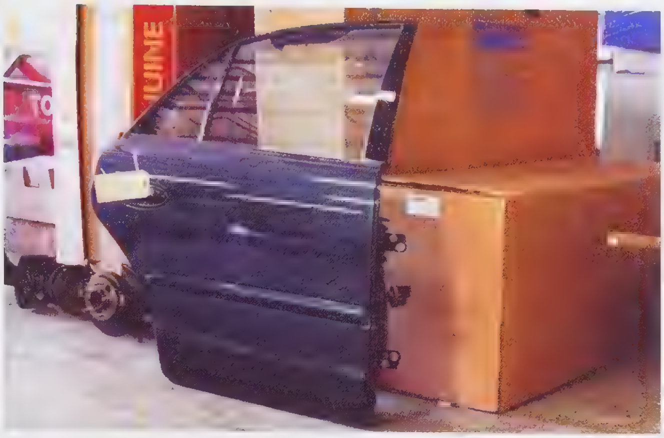


Figure 9-2. *This used right rear door assembly includes the window glass, regulator, and hinges.*

Used parts are specified because they cost less than OEM parts. However, used parts may have previously repaired damage. Always check used parts carefully before installation. The availability of used parts depends on whether there is a wrecked vehicle of the desired type in a nearby salvage yard. Many salvage yards deliver parts within a specified range. Lightweight used parts, such as fenders, can be shipped by UPS. Long-distance shipping may drive the cost of used parts up to the price of OEM parts.

Aftermarket Parts

Aftermarket parts are manufactured by a company other than the one that provided the parts when the vehicle was assembled. Aftermarket parts are available for commonly replaced parts on many popular vehicles and generally cost less than OEM parts. Examples of aftermarket parts include fenders, hoods, and bumpers. See **Figure 9-3**. The fit of aftermarket parts varies. Some aftermarket parts fit very well, as well as OEM parts. Other aftermarket parts fit so poorly they cannot be used. In some cases, a poorly fitting aftermarket part can be tweaked into alignment. However, improperly formed mounting holes and inadequate welds cannot be fixed. Aftermarket parts are available from auto parts stores, as well as paint jobbers. Always check the aftermarket part for damage and fit.

Bolted Part Replacement Steps

This section briefly outlines the individual steps in replacing bolted nonstructural parts. A combination of these steps is used to complete most repairs. For example, in some cases, the replacement part is partially painted prior to installation. Areas that are inaccessible once the part is installed are painted before installation. In other instances, the part is installed and then painted on the vehicle. This allows the bolt heads to be painted. Removing and installing the bolts can chip the paint on the bolt heads.

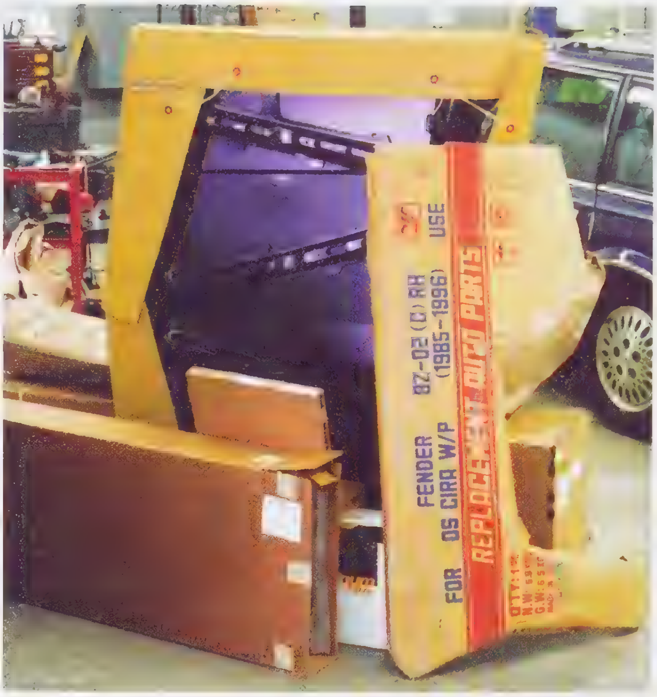


Figure 9-3. *These aftermarket parts include a fender, hood and head lamp.*

Read the Estimate

The first step in replacing a bolted nonstructural part is to study the estimate or repair order to determine exactly what needs to be replaced and what will be reused. Some components, such as nameplates, emblems, and moldings, may be undamaged and must be removed from the damaged part and installed on the replacement part.

Analyze the Damage

After studying the estimate, closely examine the part or parts to be replaced. Look for fasteners, obstructions that block access to fasteners, and electrical connectors. Carefully inspect the entire vehicle before planning the repair. Compare the estimate or repair order to the damaged vehicle. Look for discrepancies between the information included on the estimate and the actual damage on the vehicle.

Plan the Repair

When you have all the information about what will be replaced and how the parts are attached, think the repair through. A plan will help you avoid backtracking. Decide which parts you will remove first, where you will store the removed parts during the repair, and how you will install the replacement parts.

Remove the Damaged Parts

The next step is to remove the damaged parts. Begin by gathering the tools needed to remove fasteners and disconnect electrical wiring. Then disconnect all wiring that would prevent part removal. To protect the bulbs, it is best to leave them inside the turn signal or headlight housings.

Remove any obstructions that would prevent part removal and then remove the fasteners securing the part. Keep the fasteners in a labeled plastic bag. Remove the damaged parts from the vehicle. Store the damaged parts out of the work area. The damaged parts should be kept until the vehicle has been repaired and returned to its owner. This practice minimizes the chance of losing parts such as brackets and nameplates.

Be alert for hidden damage, which is evident only after parts have been removed. If additional damage is found when a bolt-on part is removed, the damage must be repaired before a replacement part is installed. For example, if a vehicle is hit at the cowl so the fender and door must be replaced, cowl damage may not be evident until after the fender and door are removed. The replacement fender and door will not fit properly unless the damaged cowl is repaired. Once the cowl is aligned, the new fender and door can be installed. Remember that a bolt-on part will fit properly only if the parts it attaches to are in proper alignment.

Fit Up

The next step in the replacement process is to position the replacement part on the vehicle. Install the fasteners that hold the part in place.

WORKING SMART

When replacing several panels on the side of a vehicle, always position the panel with the least amount of adjustment first. For example, when replacing a door and fender, adjust the door so it fits. Then adjust the fender to the door. When replacing an entire side, adjust the quarter panel first. Then adjust the doors and finally the fender.

Movable parts—doors, hoods, deck lids, and hatches—should be adjusted so they function properly and are aligned correctly with other panels. Nonmovable parts—fenders, bumpers, and header panels—should be positioned so the panel gaps are correct. All panel gaps should be uniform in width. Tapered panel gaps are a sign of misalignment and a poor-quality repair. The ability to spot misalignment is crucial in panel replacement. For example, when installing a new fender, the gap between the hood and the fender should be the same width along its entire length. Any difference in width is an indication of misalignment. The panel gap between the fender and the front door should also be uniform. To sight the fender-to-hood gap, stand at the front of the vehicle and look carefully. To compare the panel gaps on either side of the hood, a tape measure can be used. A quicker method of comparison is shown in **Figure 9-4**. A finger is inserted into the gap to maximum depth. The depth is marked. The technician moves to the other side of the panel and inserts the same finger in the corresponding gap. If the marked finger penetrates to the same depth and no further, the gaps are the same. Sighting for uniform panel gaps must become second nature to technicians.

In addition to checking for uniform panel gaps, you must sight for ***level***. The idea of level for a vehicle body is different from the concept of level used in carpentry. Level in auto body does not use the ground as a reference. The only reference is the vehicle itself. For example, bumpers must be level. For a bumper to be level, the ends of the bumper must be an equal distance from the hood or some other reference point on the body of the vehicle. If the ends of the bumper are the same distance from the reference point, the bumper is level to the vehicle.

While it would be much easier just to measure the distance between each end of the bumper and the floor, it

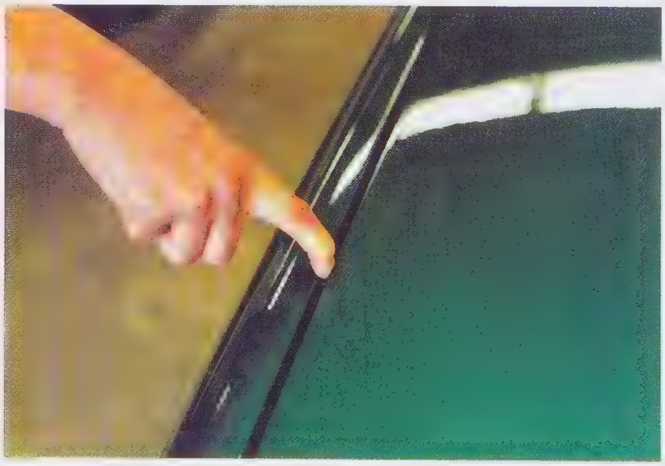


Figure 9-4. *A finger can be used to make a quick comparison of panel gaps.*

would not be as accurate. The floor may not be level. The vehicle itself may not be level either, due to unequal tire pressure or a sagging spring. All parts installed should be level *relative to* the vehicle. To gain this skill, practice by sighting a front bumper for level. Squat down about twenty feet in front of a vehicle. Look at the distance between the hood and the left end of the bumper. Compare that distance to the distance between the right end of the bumper and hood. If the hood cannot be used as a reference, pick another reference point, such as the grille, turn signals, or headlights. See **Figure 9-5**. Ignore the ground. You may need to measure the distance between the reference points and the bumper to be sure that parts are level. However, the ability to sight for level and instantly detect that a part is misaligned is invaluable.

Finally, all panels, including the fenders, hood, cowl, doors, quarter panels, and deck lid should be flush. ***Flush*** means that two or more adjacent panels are at the same surface level. **Figure 9-6** shows a non-flush fit between a fender and a door. Wind noise is caused when a door is out farther than the fender. To check panels for flush, drag your hand from one panel to another. Both panels should be the same height. A straightedge can be used to check for flush as shown in **Figure 9-7**. A panel that is not flush not only affects appearance and wind noise, but it may also affect function. For example, if a door is out compared to the fender, the door may hit the fender as it is opened. When panels are aligned properly, tighten all the fasteners.

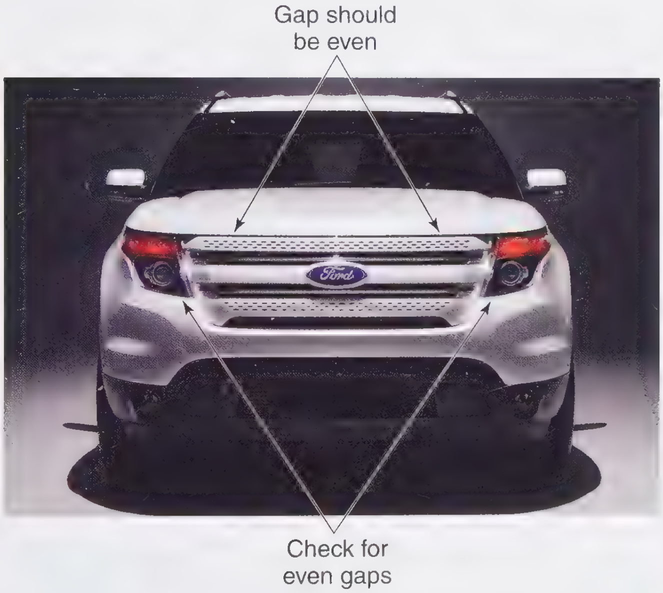


Figure 9-5. *Compare the gap between the bumper and the headlights or the hood and the grille when sighting this bumper for level. Ignore the ground. (Ford)*

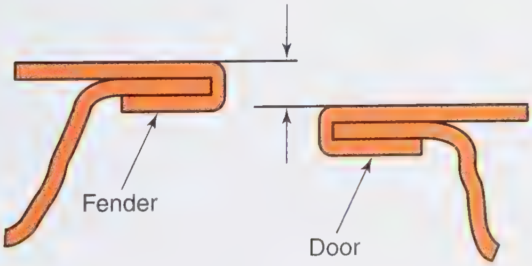


Figure 9-6. *This drawing shows two panels that are not flush. The fender is further out than the door. (Toyota)*

Final Assembly

NOTE

Final assembly often takes place after the repair area is refinished. Refinishing will be covered later in this textbook.

Final assembly consists of installing internal parts such as power window regulators, glass, and run channels on doors, as well as external parts such as moldings and nameplates on any panel. During final assembly, bring the damaged assembly to the repaired vehicle and transfer any parts that will be reused.

Replacing Specific Bolted Parts

This section describes procedures for replacing common bolted parts. These parts include steel bumpers, plastic bumpers, header panels, fenders, hoods, doors,

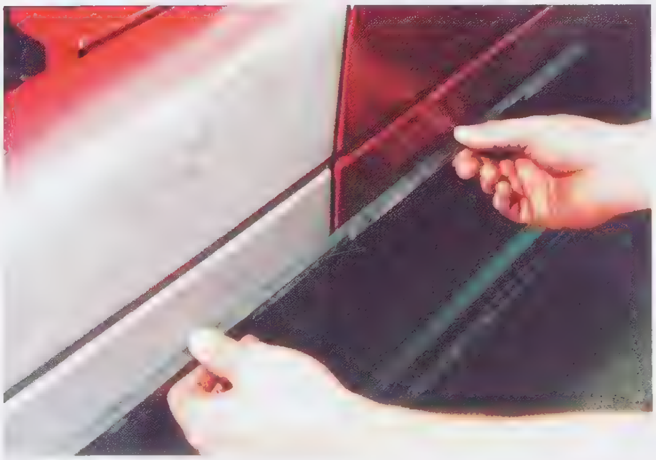


Figure 9-7. *A straightedge is used to compare the height of the fender and door.*

deck lids, rear hatches, sliding doors, and pickup truck beds. The hood, door, deck lid, rear door, and sliding doors are movable parts that must be aligned carefully in order to function. These movable parts require special care in installation and alignment.

Steel Bumpers

Steel bumpers are found on pickup trucks, SUVs, and older passenger cars. Steel bumpers may be available as a remanufactured part. Rechromed bumpers are damaged steel bumpers that have been repaired. Steel bumpers may be found on the front or rear. The rear bumper on a pickup truck is often a step bumper.

A front bumper, or a ***face bar***, is shown in **Figure 9-8**. The bumper has a plastic license plate bracket to hold the front license plate. There may also be two plastic appearance attachments: the bumper pad and the valance panel. The remaining attachments are steel. These include the bumper reinforcement and the bumper brackets. A bumper reinforcement may be bolted to the back side of the bumper. The bumper brackets are bolted to the bumper or reinforcement and the vehicle frame. Additional attachments, such as turn signals, may be found on some vehicles. Other vehicles may have a shock absorber-like device bolted between the frame and the bumper reinforcement. This is called an isolator. The isolator is designed to absorb a specified amount of force without being damaged.

A bumper bolt is shown in **Figure 9-9**. The square shank fits into a square hole in the bumper. When turning a nut on the bumper, the square shank will not turn in the hole. Bumper bolts may be chrome plated for appearance.

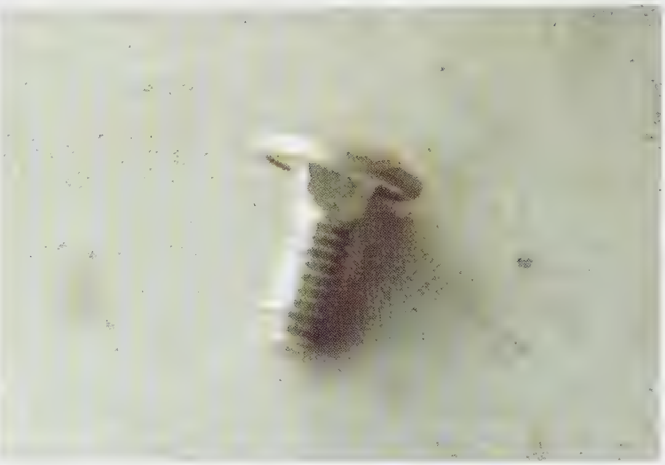


Figure 9-9. *Bumper bolts have a shoulder to slip into a square hole in a bumper.*

A rear bumper, **Figure 9-10**, may have a plastic step pad, center pad, and impact strips. The steel brackets are bolted to the bumper and frame. The rear license plate is mounted in the center of the bumper. The license plate lamps are found on either side of the license plate frame. These bumpers may have a trailer hitch installed.

Both the front and rear bumpers shown in these examples are incapable of absorbing impact. If a force greater than the yield point impacts the bumper, the bumper will be damaged. The damage force will also be transferred to the bumper brackets and the vehicle's frame. Some front steel bumpers are mounted directly to the frame.

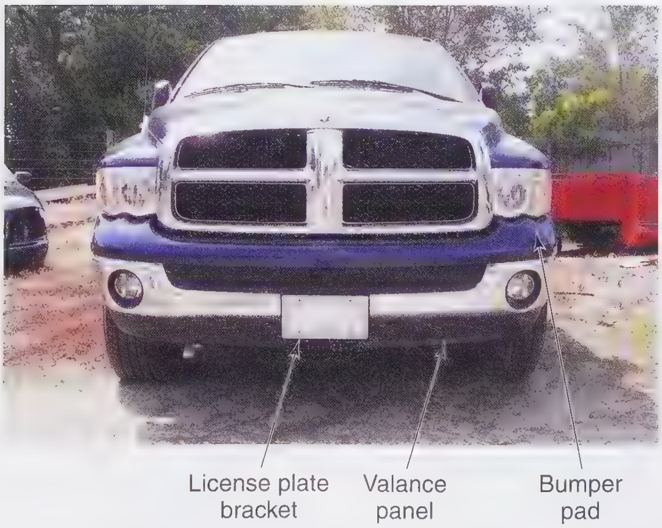


Figure 9-8. *This front bumper is made of steel and plastic.*

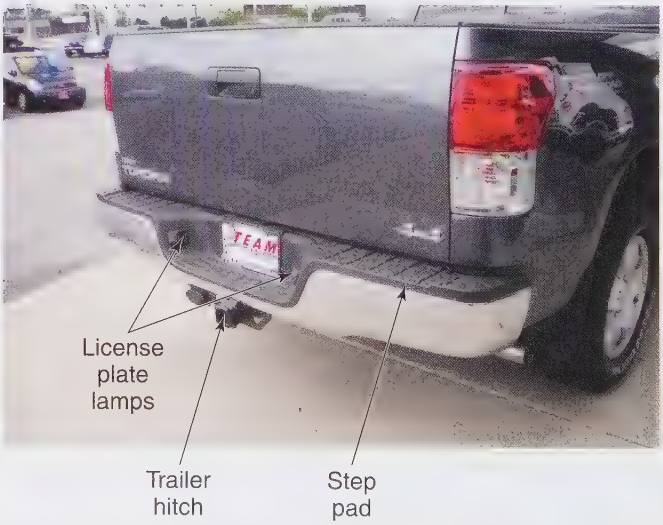


Figure 9-10. *This is a rear bumper on a pickup truck.*

Removing a Steel Bumper

One goal in removing any damaged part is to avoid creating additional damage. Also, the removal must be fast. Disconnect any electrical wires, and then disconnect the bumper brackets from the frame. Then the bumper assembly is pulled off as a unit. If the brackets are welded to the frame, the bumper is unbolted from the brackets. To access the bumper bolts, the grille or plastic top cover on the bumper may need to be removed. If the bumper bolts are rusty, heat them with a torch before loosening them. This will make removal easier. If a bumper bolt turns in the hole, use a cut-off wheel to grind off the head. Badly bent steel bumpers can be cut off with a torch or a plasma cutter.

After removing the bumper, place it on sawhorses. Remove all the components that are to be transferred to the new bumper. Damaged components can be left on the damaged bumper unless they prevent the removal of a needed part. Plastic appearance attachments are often held in place with tabs molded into the plastic. **Figure 9-11** shows how to squeeze the tabs to allow them to slip out of the mounting hole. Other components, such as brackets, are simply bolted to the bumper. Plastic rivets can be removed by pulling them with an upholstery tool.

NOTE

Fasteners are often located in confined areas, making it difficult for the technician to see them. When removing hidden fasteners, the technician must work by feel, using fingers to gauge the size and type of fastener. In a confined area, an air ratchet is convenient for removing bolts and nuts. Installing hidden fasteners can be difficult if bolt hole alignment is not perfect. Because the technician cannot see if the alignment is correct, an alignment tool can be inserted into the bolt holes to line them up before the bolt is installed.

Installing a Steel Bumper

Place the new bumper on sawhorses. Use foam blocks or cardboard between the new bumper and the sawhorses to prevent scratches to the new bumper. Check plastic appearance components for fit before installation. New plastic parts may need to be stretched slightly to fit. Line up the mounting tabs with the holes. When the fit is correct, use a rubber mallet as shown in **Figure 9-12** to tap the mounting tabs through the holes. Install any bolted or riveted plastic components.

NOTE

If the holes for the mounting tabs in an aftermarket bumper are too small, enlarge the bumper holes to accept the tabs or slightly trim the tabs to fit the holes.

If two people are available to install the bumper, position one technician at each end of the bumper and lift it into place. If only one technician is available, put the bumper on a floor jack and raise the bumper up to the vehicle. Install the bolts and nuts, and tighten fasteners enough to hold the bumper in place.

Figure 9-13 shows a front steel bumper that is not aligned properly. Some steel bumpers have a large amount of alignment movement. Others have very little possible adjustment. If the bumper is not level, decide if one end is too high or too low. Then, make adjustments as needed. Tighten the bolts and again check for level. Once the bumper is level, check to see if the bumper ends are the same distance from the fenders. The bumper brackets may allow some movement from left to right. Move the bumper to the center so the distance to the fenders is equal on both sides of the vehicle.

Next check to see that the wheel opening and the bumper end align. A bracket may need to be moved forward

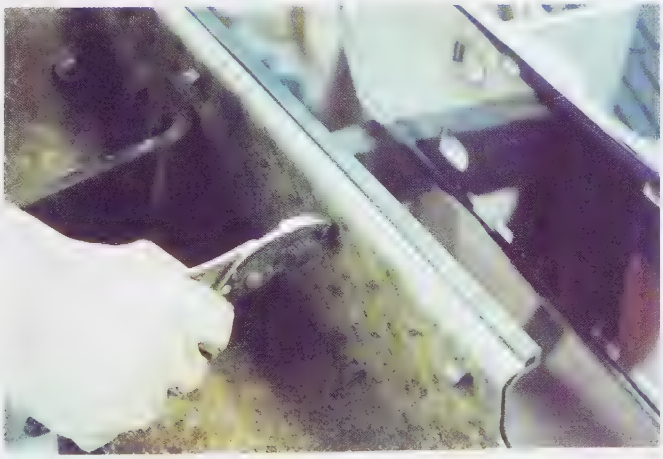


Figure 9-11. *Bumper pad tabs can be squeezed together to allow the tabs to slip out.*

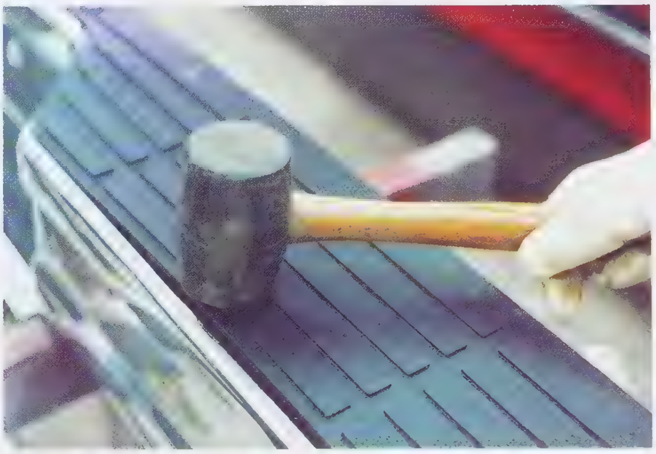


Figure 9-12. *A rubber mallet is used to tap the bumper pad tabs into place.*

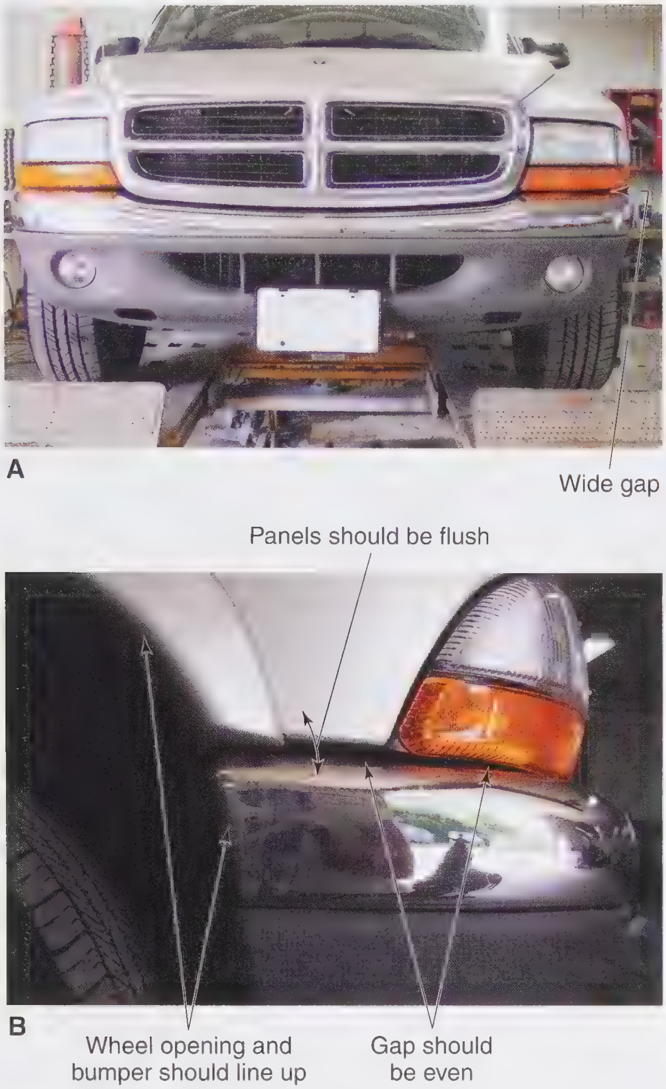


Figure 9-13. *This steel bumper is not properly aligned. A—The bumper is not level. Compare the gaps between the left and right turn signals and the bumper. B—The bumper is not level and the wheel opening and bumper do not line up. The other side of the vehicle shows the same problem.*

or rearward to properly set the bumper. If all these checks are good, the bumper should be correctly aligned. Bumper brackets may permit up-and-down, side-to-side, and front-to-back movement. If alignment is difficult, loosen (but do not remove) the bolts or nuts on all the brackets. Use a floor jack to set the bumper in its proper location. Adjust all the brackets. Tighten the nuts and bolts.

NOTE

If the bumper cannot be aligned, the brackets (if reused) or the frame may be bent. Check and straighten the brackets or the frame. If necessary, the brackets can be replaced.

On some vehicles, the bumper brackets are welded to the frame. To replace these brackets, cut off the damaged bracket and straighten the frame end if necessary. The replacement bracket has a J-clip and bolt provided. A ***J-nut,*** or ***J-clip,*** is a nut that does not need to be held in place with a wrench while loosening or tightening the corresponding bolt. The J-nut slides in place over the hole in the bracket. The design of the J-nut prevents it from turning as the bolt is installed or removed. Install the replacement bracket with the J-nut and bolt. Install the bumper and check the alignment. Adjust the position of the bracket as needed. Remove the bumper and weld the bracket to the frame.

Plastic Bumpers

Most passenger cars have plastic bumpers. Plastic bumpers may consist of an outer flexible ***bumper cover*** and an inner hidden reinforcement. The cover is plastic and the reinforcement is steel. The cover may also be called a fascia. Another type of plastic bumper is made entirely of plastic. Passenger car front bumpers are designed to withstand a specified amount of impact force without incurring any damage.

A flexible plastic bumper cover assembly is shown in **Figure 9-14**. The major part of this assembly is the bumper cover, which may be painted the same color

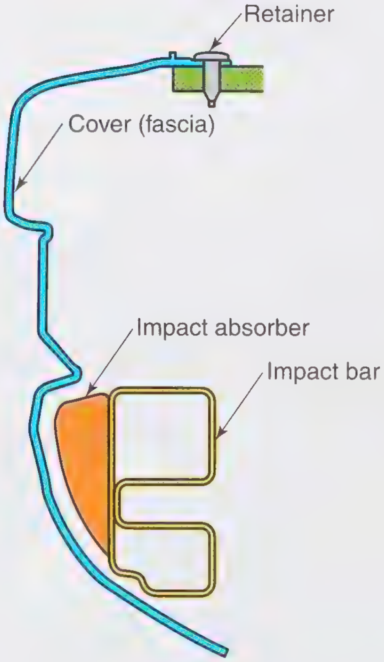


Figure 9-14. *This front bumper assembly consists of a plastic cover, a foam-type impact absorber, and a steel reinforcement. (Toyota)*

as the vehicle. Inside the cover is a foam-type ***impact absorber***. Behind the impact absorber and bolted to the lower frame rails is the steel, aluminum, or plastic ***impact bar***. Some vehicles have shock absorber-like ***isolators*** bolted between the impact bar and the frame rails. The bumper cover may be held in place with retainers. See **Figure 9-15**. Turn signals or marker lights may be found in some bumpers. A license plate bracket and air deflectors may also be included. Rear bumpers are similar. A one-piece plastic bumper has a slide to fit on a retainer. The bumper is bolted to the lower frame rails. The bumper may have a license plate bracket and an impact strip.

Removing a Plastic Bumper

The first step in removing a plastic bumper is to disconnect any lamps. If the bolts or nuts that fasten the impact bar or one-piece bumper to the frame are accessible, remove them. Remove the bumper as an assembly. There may be retainers around the edges of the bumper. To remove bumper cover retainers, use an upholstery tool to raise the center stud as shown in **Figure 9-16**. If the vehicle has isolators, leave them attached to the frame rails.

If there aren't any bumper nuts or bolts accessible, the cover will need to be removed separately. See **Figure 9-17**. Search the edges of the bumper for retainers. Usually the retainers will be at the fenders; along the top of the bumper, under the hood; and along the bottom, under the radiator support. Remove these retainers and pull off the cover. The impact absorber may fall out or it may be attached to the impact bar with retainers.

The impact bar bolts will be accessible with the cover and the impact absorber out of the way. Badly damaged covers can be removed with a cut-off tool.

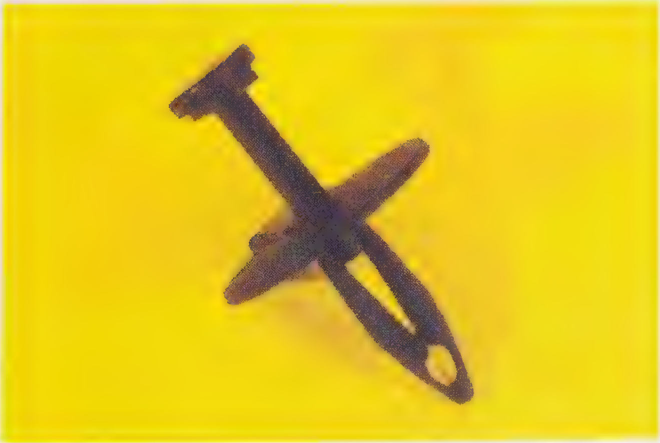


Figure 9-15. *This is one type of plastic bumper retainer. The center stud is in the raised position. Pushing in on the stud locks the retainer in place.*

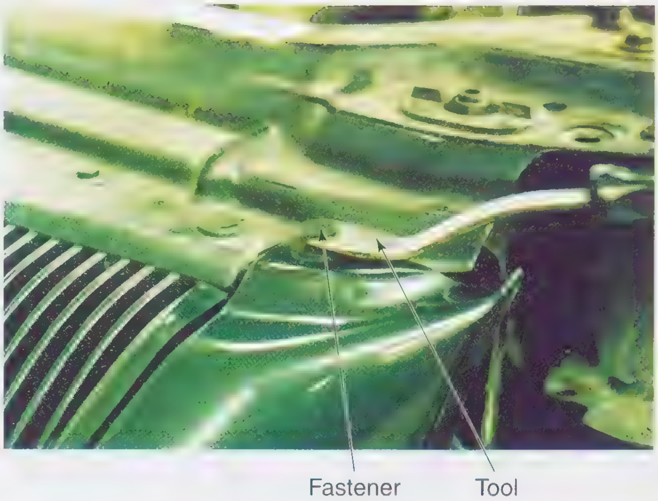


Figure 9-16. *Raising the center stud unlocks the retainer.*

Figure 9-17. *To remove this plastic bumper cover, these technicians must locate and remove the retainers.*

If the bumper was removed as an assembly, remove any retainers and separate any parts that will be reused. If all the bumper components are to be replaced, don't bother to disassemble the bumper unless the retainers are needed. Position the new bumper components so that as parts are removed from the damaged bumper, they can be transferred to the new bumper.

Installing a Plastic Bumper

If the bumper cover has been painted, be sure not to scratch the paint during bumper assembly and installation. If the bumper is to be installed as an assembly, start by placing the cover face down on foam padded (or otherwise protected) sawhorses. Position the impact absorber and impact bar inside the cover. Install the retainers by pushing the ears through the holes and then pushing on the studs. Two technicians should install the assembly on the vehicle. One technician holds the bumper in position, while the other technician tightens the bolts under the vehicle. If the bumper is not installed as an assembly, first mount the impact bar on the vehicle. Check the bar for level. Then, position the impact absorber and bumper cover. Install the retainers. A one-piece plastic bumper easily slides onto the retainers and then bolts to the lower frame rails.

There usually is not much adjustment in a plastic bumper. In most cases, only the height of the impact bar can be changed. The alignment checks for a plastic bumper are shown in **Figure 9-18**. If the bumper is not level or if the height is incorrect, adjust the height at the impact bar. Make sure the edges of the bumper are aligned with the rest of the vehicle. If the bumper cover will not line up after adjusting the height of the impact bar, check the unirails, the radiator support, and the aprons for damage. Repair these as needed.

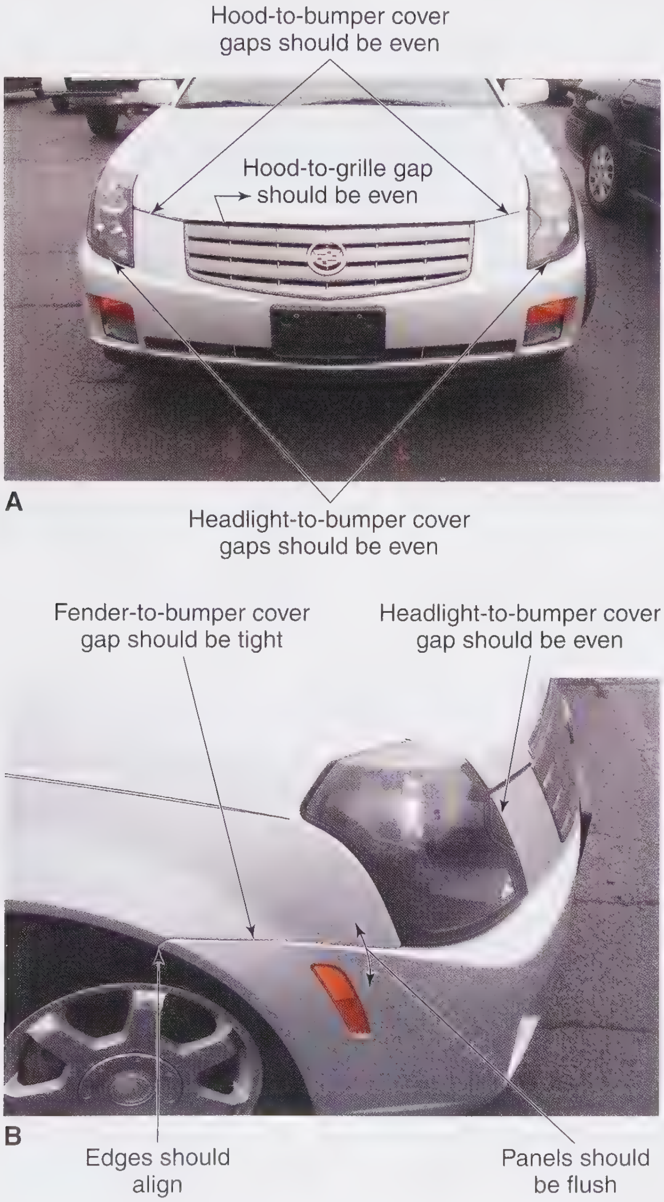

Hood-to-bumper cover gaps should be even
Hood-to-grille gap should be even
A
Headlight-to-bumper cover gaps should be even
Fender-to-bumper cover gap should be tight
Headlight-to-bumper cover gap should be even
B
Edges should align
Panels should be flush

Figure 9-18. *A—The bumper should be level and the gaps should be uniform as shown here. B—The bumper cover should fit tight and line up with the fender.*

Header Panel

The ***header panel*** is also called the headlight mounting panel or the grille panel. On some vehicles, the header panel is an appearance panel. An ***appearance panel*** is readily visible from outside the vehicle. Most appearance header panels are painted the same color as the vehicle. Header panels are usually made of plastic. Non-appearance header panels are commonly called headlight mounting panels. Non-appearance panels are not painted. **Figure 9-19** shows the parts of a plastic header panel. The components include the headlight assemblies, the grille, and the brackets. The header panel is mounted to the fenders with studs and nuts.

Removing a Header Panel

The first step in removing a damaged header panel is to disconnect the headlights or marker lamps. Leave

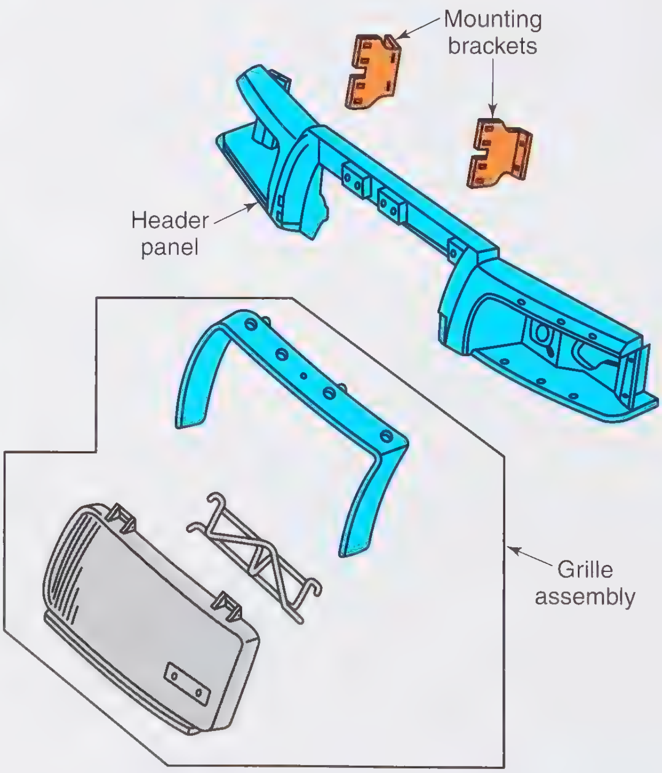

Mounting brackets
Header panel
Grille assembly

Figure 9-19. *These are the parts of a typical header panel.*

the bulbs in the lamps. If the headlights block access to the bolts, remove the headlights and the trim. Next remove the nuts from inside the fenders or unbolt the header from the fenders. The fender liner may have to be removed to accomplish this task. There also may be a center bracket that must be removed.

NOTE

If two or more damaged parts are connected, remove them together rather than taking the time to unbolt them.

If a fender and the header panel are both damaged, remove the fender and header together. Do not take the time to unbolt the header panel from the damaged fender. Badly damaged header panels can be removed with a cut-off tool.

The header panel is mounted to the fender by a stud that screws into a plastic mount in the panel. The stud is inserted through a hole in the front flange of the fender. A nut holds the fender to the stud. Occasionally, the stud will break loose, stripping the threads from the plastic mount in the header panel. When the nut is turned to remove the nut from the stud, the stud turns with the nut. When this occurs, simply pull the header from the fender. Then grab the stud with locking pliers and turn the nut. Before reinstalling the header panel, apply plastic adhesive to the mount and install the stud. The plastic adhesive will hold the stud in place.

Remove any parts that will be used in the replacement header panel, such as the headlight assemblies or grille. The headlights may have a special type of retainers or clips.

NOTE

Place the nuts, bolts, clips, and other panel components in labeled plastic bags. See Figure 9-20. All the fasteners for one panel or component should be kept together.

Installing Header Panel

If an appearance header panel has been painted, assemble the header on foam-padded sawhorses. If padded sawhorses are not available, install the header panel on the vehicle and fit all of the components onto it.

The header panel is installed by positioning the panel so the mounting studs can slide into the holes in the fenders. Once the header panel mounting studs are positioned, install and tighten the nuts on the mounting studs. Some header panels have a filler panel that is bolted to the header panel and the radiator support. Install the filler panel after the header panel is aligned.

Header panel alignment is dependent on the position of the fenders and radiator support. These components must be properly aligned before aligning the header panel. Alignment checks for a header panel are shown in **Figure 9-21**. Check the header panel for level. On an appearance header panel, make sure that the edges of the header panel align with the front edges of the fenders. Check the gap at the hood and make sure the body lines align properly. There is only a small adjustment possible on a header panel. A slight up-and-down and left-to-right movement is all that is allowed. If the gap between the header panel and the hood is not even, check the fender alignment. One fender may be positioned farther forward than the other fender. This situation would cause an uneven gap. Also check the hood alignment. Realign panels as needed.

Figure 9-20. *Keep nuts and bolts in a labeled bag.*

Fenders

Fenders can be made of steel or plastic. Steel fenders can be either a skin fender or a reinforced fender. A ***skin fender*** is one piece of shaped metal. Vehicles with a welded front inner structure, such as most unibody vehicles, have skin fenders. A ***reinforced fender*** is found on vehicles that do not have a welded front inner structure. The reinforced fender has an outer skin and an inner panel. The two parts are welded together. Vehicles with a bolted-on radiator support, such as some pickup trucks, have reinforced fenders. If a reinforced fender is removed, the side of the engine is easily accessible.

Parts of a fender are shown in **Figure 9-22**. These parts may include the fender liner, side marker lamp, hood bumpers, moldings, and antenna. Fenders are installed with nuts and bolts. The nuts are either J-clips or they are welded in place. The fender or the cowl of the vehicle may have a tab, or protrusion, on which a J-clip is inserted.

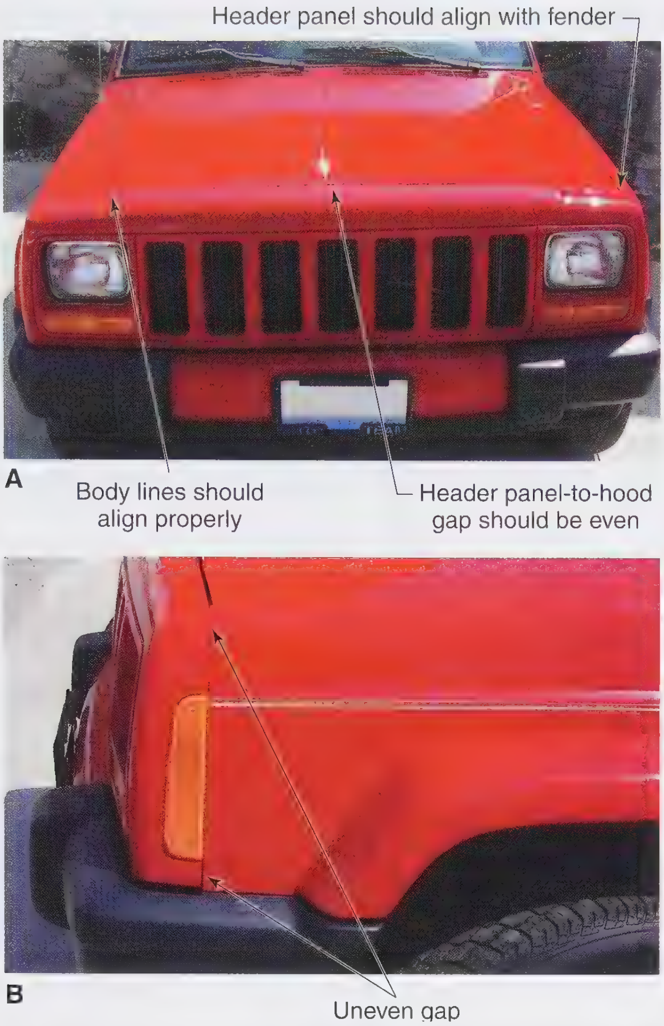

Header panel should align with fender
A
Body lines should align properly
Header panel-to-hood gap should be even
B
Uneven gap

Figure 9-21. *A—These checks should be made when aligning a header panel. B—The header-to-fender gap on this vehicle is slightly uneven. Try to tighten the bottom mounting stud nut to close the gap.*

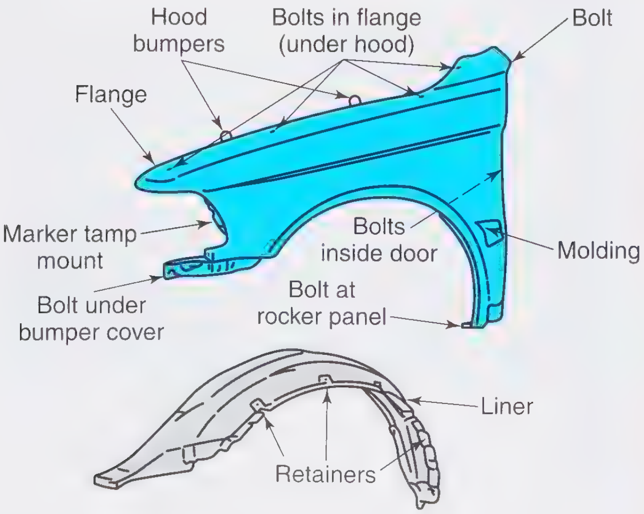

Hood bumpers
Bolts in flange (under hood)
Bolt
Flange
Marker tamp mount
Bolts inside door
Molding
Bolt under bumper cover
Bolt at rocker panel
Liner
Retainers

Figure 9-22. *These are the parts of a skin fender. (Mitsubishi)*

This tab is not visible unless the door is open and may be accessible only when the fender liner is removed.

The fender liner may be held in place with plastic rivets or single-use retainers. A single-use retainer is shown in **Figure 9-23**. Plastic rivets are removed by raising the center pin and prying out the rivet. Single-use retainers are pulled out with an upholstery tool. Removal usually damages the retainers, so they cannot be reused.

Removing a Fender

Before removing a fender, the front bumper may have to be removed to access the fender fasteners. On a reinforced fender, the hood hinge may be bolted to the fender. When this is the case, remove the hood hinge and support the hood. Fenders commonly have bolts along the fender flange (under the hood), at the bottom (on the rocker panel), at the rear, and at the front. There may be a hidden bolt or nut, accessible only after removing the fender liner. The fender liner should be removed. Use an air chisel to vibrate rusty bolts. Disconnect any lamps, remove any fasteners holding the fender in place, and remove the fender.

NOTE

Do not remove marker lights, moldings, etc., from the damaged fender. These parts should remain on the fender until you are ready to transfer them to the new fender. Leaving the parts on the original fender until they are needed prevents them from being lost and helps you remember where they belong.

Installing a Fender

Some shops paint the edges of the replacement fender before it is installed. Other shops do all the

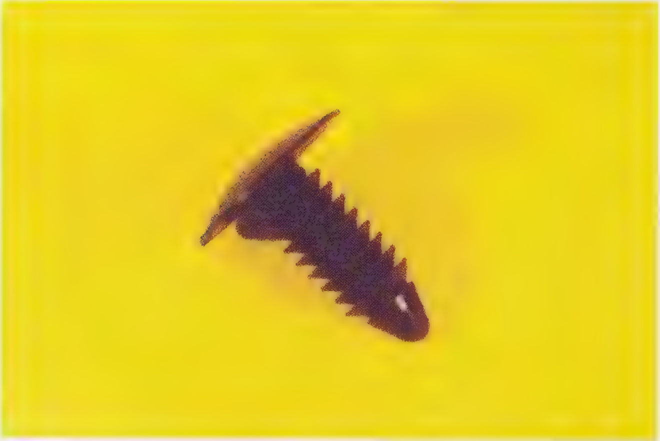


Figure 9-23. *This is a single use retainer. Removal of this retainer destroys the holding capability.*

painting after the part is on the vehicle. Regardless, the marker lamps and moldings are installed after the fender is installed on the vehicle and painted. Position the fender and tighten the bolts enough to prevent movement. Make sure that the door opens without hitting the fender. Finally, install the hood bumpers.

NOTE

If you have difficulty getting the fender to fit properly, make sure the tab, the hidden nut, or the bolt it attaches to is in the proper place. Also check the unibody or frame for damage.

The alignment checks for a fender are shown in **Figure 9-24**. The upper front and rear corners of the fender should align with the corners of the hood. The first gap to check is the fender-to-front door gap. If the front door is properly positioned, it can be used as a reference. The gap between the fender and door should be even, not tapered. A taper indicates that the front of the vehicle may be high or low. If the gap is tapered, try moving the fender forward or rearward at the bolts on the rocker panel. If the gap between the fender and the door is too narrow or too wide, move the fender at the bolts under the hood. Once the gap is correct, tighten the rocker bolts.

Next, check the hood-to-fender gap. The hood must be correctly adjusted to serve as a reference. Again the gap should be uniform. The gap should also match the fender-to-hood gap on the opposite side of the vehicle. Adjust the fender in or out to make the proper gap. If the fender cannot be adjusted to make the gap correct, then move the fender edge. See **Figure 9-25**. Tighten the underhood fender bolts first. Figure 9-25A shows how to make the gap wider. A block of wood is used to spread out and soften the hammer's blow. The intent is to drive out the edge of the fender. This will give a slight change (about 3 mm) in gap width. Position the wooden block on the lip of the fender and tap the lip out. Do not wrinkle the fender. To make the gap narrower, tighten the fender bolts and use a body chisel to drive the bottom of the fender flange out. See Figure 9-25B. This technique moves the fender flange out but does not move the lip. Once the flange is moved, the bolts can be loosened and the fender moved inward to make the gap narrower. Tighten the underhood fender bolts once the gaps are correct.

Now check to see that the fender is flush to the hood and front door. The hood and fender top should be at the same height and the body line on the fender should align with the body line on the door. If the fender is not flush with the hood, then the hood is usually adjusted to fit the fender. The fender should be flush with the door. If the fender is positioned inward compared with

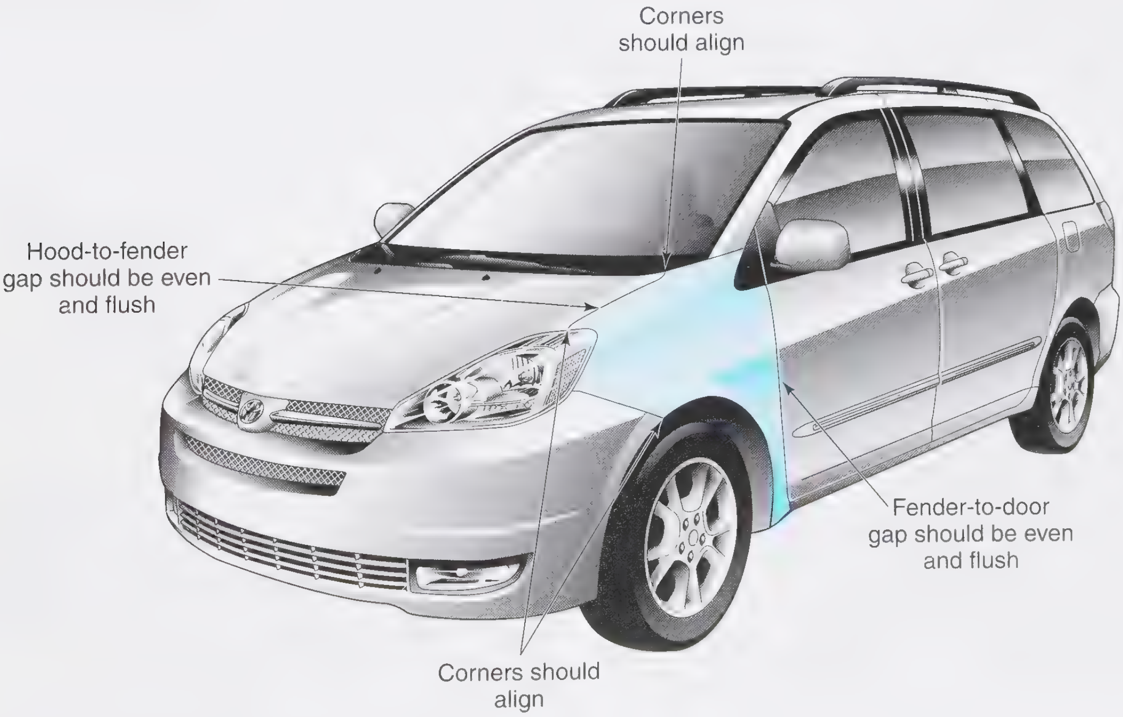

Corners should align
Hood-to-fender gap should be even and flush
Fender-to-door gap should be even and flush
Corners should align

Figure 9-24. *To check fender alignment, look at the door to fender gap first and correct if necessary. Then look at the hood-to-fender gap and make necessary adjustments. (Toyota)*

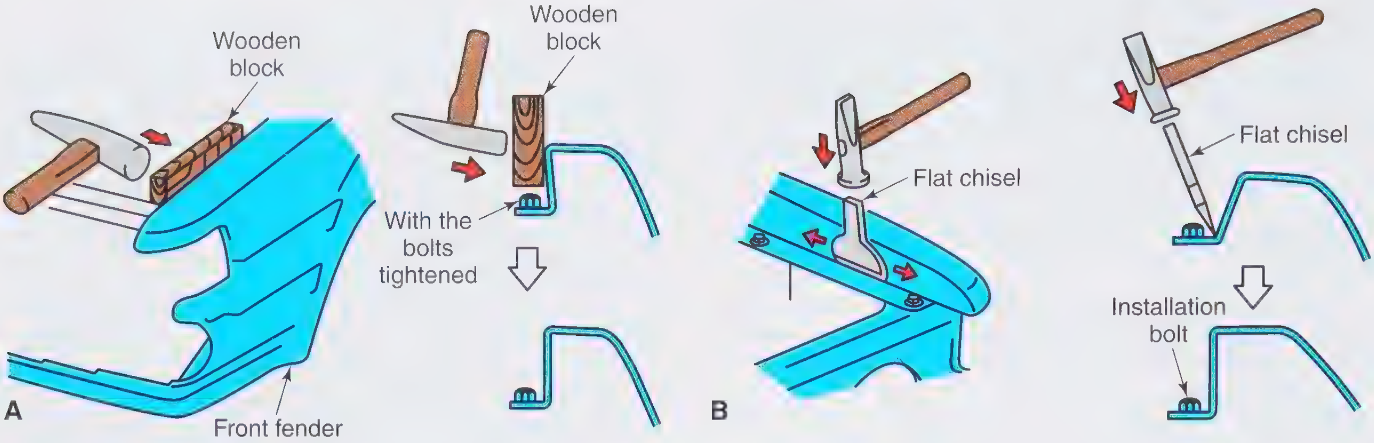


Figure 9-25. *A—A block of wood can be used to move the edge of a fender out. B—This technique is used to make the fender to hood gap narrower. (Toyota)*

the door, the fender can be "spooned out" as shown in **Figure 9-26**. The edge of the door is taped to prevent damage. The spoon is placed behind the fender and the door is used for leverage. The fender is brought out until it is flush or positioned out slightly more than the door.

If the fender is protruding in comparison to the door and there isn't any adjustment on the fender, bend the fender in with a body chisel placed on the body line. Use hand pressure only. Do not hammer on the chisel. If the fender does not have a body line, simply use hand pressure to bend it in. Only a slight amount of movement is possible. Make sure the door opens and closes without hitting the fender when making flush adjustments.

Once the new fender has been installed, the parts remaining on the original fender can be moved to the new fender. Marker lamps may be held in place with sheet metal nuts. Use a deep-well socket to unbolt these nuts. Remove glued-on moldings with a heated putty knife or a molding chisel.

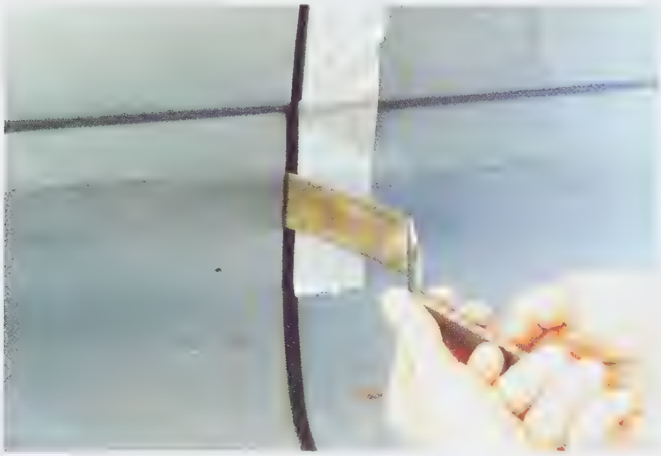


Figure 9-26. *To raise a fender edge to be flush, tape off the door and pry out on the fender with a spoon. If possible, locate the spoon near a body line. The area near a body line is stronger and less likely to bend.*

WORKING SMART

When transferring components from the damaged part to the new part, set the parts side by side. Unbolt one component and install it on the new part before moving on to the next component. This procedure will help prevent confusion.

Hood

Hoods can be made of steel, aluminum, or plastic. Most vehicle hoods are opened at the front. The parts that are found on a typical hood are shown in **Figure 9-27**. Hood hinges are bolted to the hood and welded to the cowl or bolted to the cowl or fenders. The hood is held shut by the ***striker*** and the ***hood latch***. A safety catch prevents the hood from flying open if it is not latched. Some vehicles have a hood insulator and an underhood lamp. Hoods may also have emission control stickers. Hood ***stops*** keep the hood at the proper height. The hood is held open by a prop rod or by springs in the hinges. A release cable, pulled from inside the passenger compartment, unlocks the latch. Some vehicles have a ground strap bolted to the hood and the cowl.

Removing a Hood

To remove a damaged hood, the hood must be opened. Collision damage may misalign the latch so much that it will not release the striker. Pull the cable

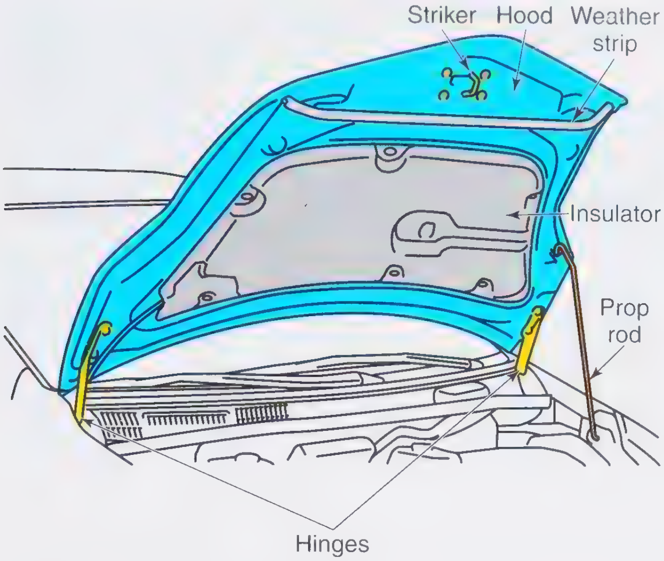


Figure 9-27. *This drawing shows common hood components. The insulator is a fabric pad clipped to the inside of the hood. (Toyota)*

release knob from inside the passenger compartment. The hood may pop open. If it does not, one technician should pull on the release while another pulls up on the hood. See **Figure 9-28**. If this does not work and the latch bolts are accessible, either through a broken out grille or from under the vehicle, remove the cable release and unbolt the hood latch. If this is not possible because of radiator support damage, insert a long pry bar under the hood and pry open the hood. If this does not work, use a cut-off tool to cut off the striker area of the hood. Once the hood is open, disconnect the underhood lamp and ground strap. Position a technician at each hood hinge, unbolt the hood from the hinges, and remove the hood. If only one technician is available, tape protective cardboard to the windshield and position a prop rod at each front corner of the hood. Unbolt one hinge and set that corner of the hood against the cowl. Then, unbolt the other hinge and remove the hood from the vehicle.

If the hood has an insulator pad, simply use an upholstery tool to remove the pad clips. The plastic pad clips are easily broken when removed, especially on older vehicles. The hood may have a weather strip that is clipped in place. These clips are also removed with an upholstery tool. Unbolt any remaining parts.

Installing a Hood

Usually the underside of the replacement hood is painted before installation. Install any bolted parts and then place the insulator pad in position. Use new clips to hold the insulator pad in place.

Remove the hood latch. This should be done on all panels that open and shut. The reason is that if the hood is installed and the alignment is incorrect, it may be difficult to get the hood open after shutting it. To avoid this dilemma, remove the latch until the alignment is set. Then install and align the latch.

Make a quick X-check of the hood opening. If the legs of the X are within 6 mm of each other, the hood can be aligned. If there is more than a 6 mm difference between the legs of the X, there is an out-of-square condition in the hood opening. The hood cannot be adjusted to fit properly.

If two technicians will install the hood, position the tools and bolts within easy reach of each hinge. Each technician supports one side of the hood and installs the bolts as shown in **Figure 9-29**. The procedure for one technician to install the hood is shown in **Figure 9-30**.

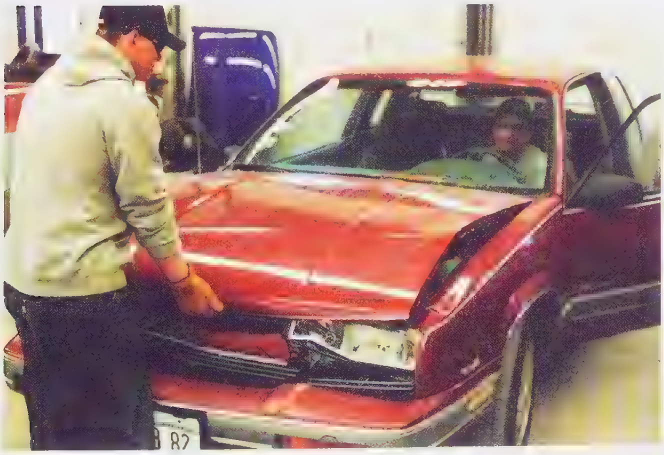


Figure 9-28. *Two technicians are often needed to open a damaged hood. The technician in the car is pulling on the hood release while the other technician pulls up on the front of the hood.*

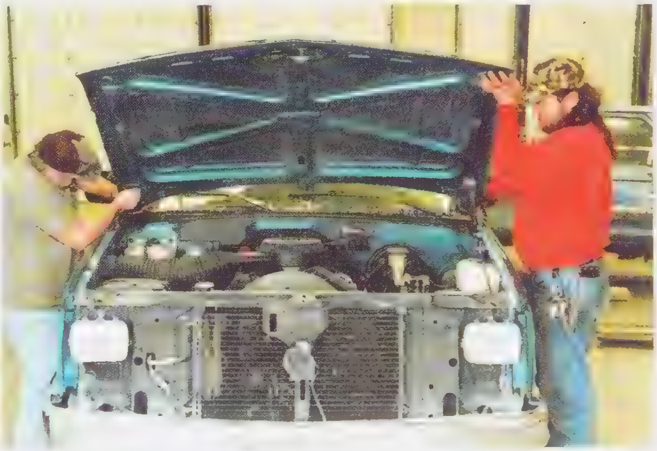


Figure 9-29. *When two technicians install a hood, each technician bolts one hinge to the hood.*

Figure 9-30. *Use the prop rod to hold the hood when one technician installs a hood.*

The hood rear corners are set on the cowl and the hood is held open by prop rods. The technician installs the bolts in the hinges. Position bolt-on replacement hinges as close as possible to the position of the original hinges. Welded-on hinges should be positioned to check hood alignment before welding. Drill holes in the hinges and the cowl. Insert J-clips in the cowl and bolt the hinge in place. Install the hood and check the alignment. Once the alignment is correct, the hinges can be welded in place.

Figure 9-31 shows the alignment checks for a hood. The first check is made at the cowl vent panel or windshield. If the gap is even, the hood is on straight. If the gap is not even, adjust the position of the hood by loosening the hinge bolts and moving the hood forward or rearward. Make sure the gap is straight. The corners of the hood should align with the upper front corner and upper rear corner of the fender.

Next check the gaps at the fenders. If the gap or gaps are tapered, adjust the fenders to match the hood. If one side is narrow and the other side is wide, push the hood over as shown in **Figure 9-32** or loosen the hinge bolts and move the hood over.

NOTE

If the hood-to-fender gap is correct on one side and tapered on the other side and the hood gap at the cowl vent panel is even, adjust the fender on the side of the taper.

Once the rear and side gaps are equal, look at the front gap. If there is an appearance header panel, plastic bumper cover, or headlights, the gap should be even. If the gap is not even, adjust the header panel or bumper cover. Headlights cannot be adjusted to fit. On all vehicles, check the height of the hood at the front. Adjust the hood stops, **Figure 9-33**, on the radiator support to make a flush fit between the hood and the fenders.

Once these are aligned, install the hood latch. Position the latch so the striker hits in the center of the latch.

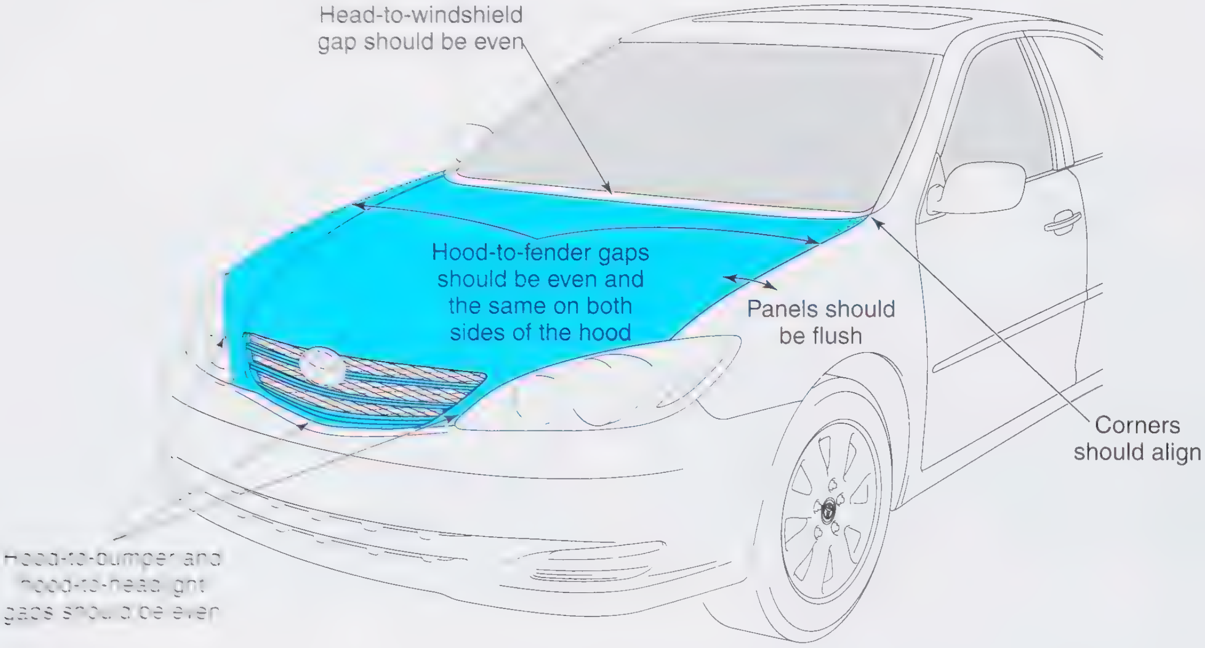

Head-to-windshield gap should be even
Hood-to-fender gaps should be even and the same on both sides of the hood
Panels should be flush
Corners should align
Hood-to-bumper and hood-to-headlight gaps should be even

Figure 9-31. *These are the checks that should be made when aligning a hood. (Toyota)*

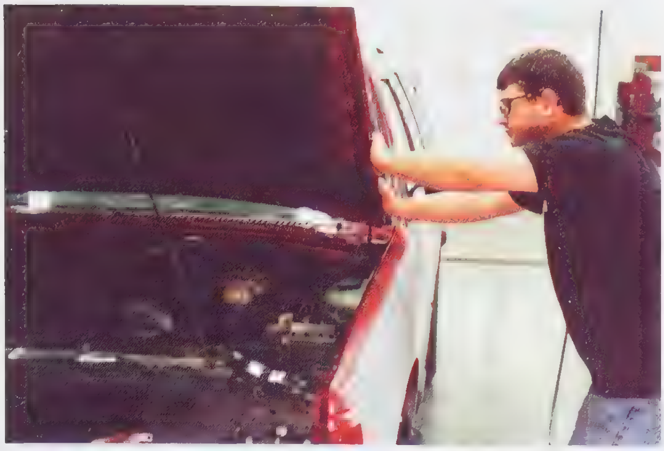


Figure 9-32. *To widen one fender-to-hood gap and narrow the other, a technician pushes on hood in the area of the hinge.*

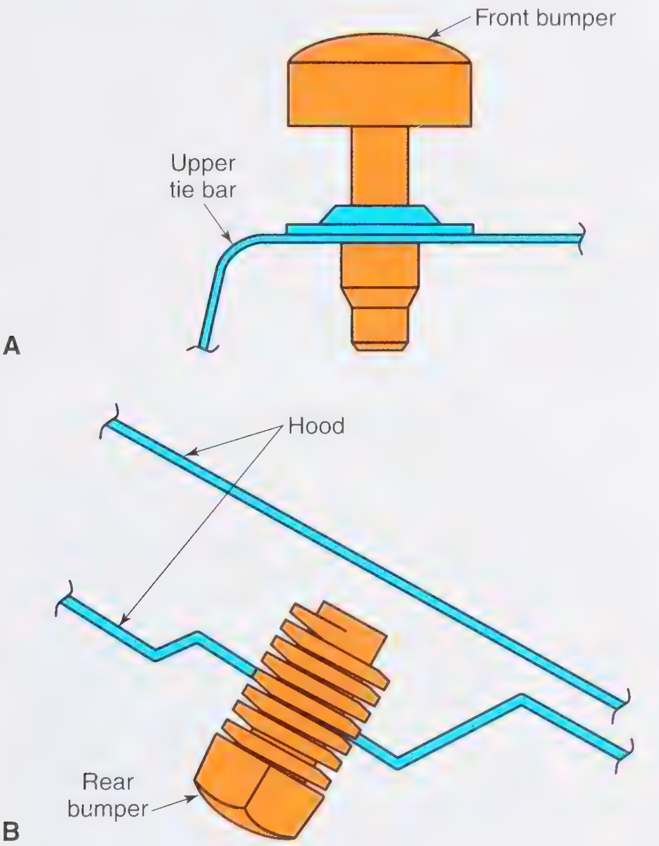

Front bumper
Upper tie bar
A
Hood
Rear bumper
B

Figure 9-33. *Adjusting the hood stops will set the height of the hood. Some hoods have front and rear stops. Most hoods have only front stops. A—Front stop. B—Rear stop.*

See **Figure 9-34**. A misaligned latch will pull the hood to one side. When the hood latch is released, the hood will jump from one side to the center. If the hood jumps to the left when opened, the latch is too far to the right. Move the latch to the left to center it.

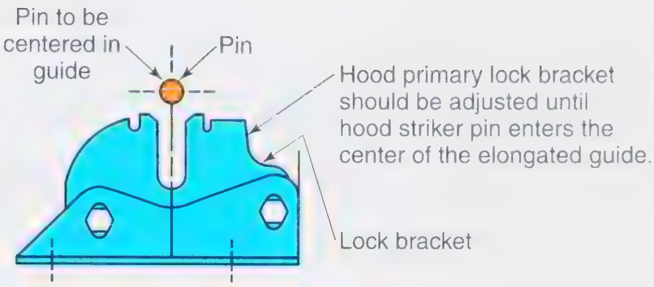

Pin to be centered in guide
Pin
Hood primary lock bracket should be adjusted until hood striker pin enters the center of the elongated guide.
Lock bracket

Figure 9-34. *The striker should be centered in the latch.*

The hood should latch completely when it is dropped from about one foot above the radiator support. With the hood shut, pull up on the front of the hood. There should not be any movement. If there is up-and-down movement in the hood, the latch is too high and the striker is not fully engaged. Lower the latch and recheck for movement. With the hood latched, pull the cable release. The hood should pop up.

If the hood does not pop up when the cable is pulled, oil the latch. Close and open the hood a few times to help distribute the oil. If this does not work, check the striker. An impact on the hood could have bent the striker. A striker can be straightened by holding it with locking pliers and bending it back into shape. To function properly, the striker must point straight down.

Check the height of the hood at the rear. If the hood and fenders are not flush, raise the hood hinge up or down to adjust the height. If the height of the hood hinge cannot be adjusted, a shim can be added to change hood height. See **Figure 9-35**. This technique also works on deck lid hinges. Figure 9-35A shows how adding a shim

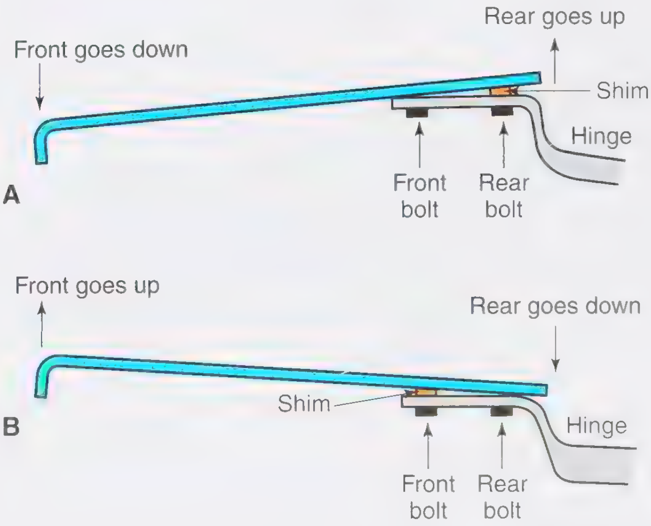

Front goes down
Rear goes up
Shim
Hinge
A
Front bolt
Rear bolt
Front goes up
Rear goes down
Shim
Hinge
B
Front bolt
Rear bolt

Figure 9-35. *Shims can be added or removed to change hood height.*

between the hood and the hinge at the rear bolt raises the rear of the hood and lowers the front of the hood. If the shim is placed at the front bolt, Figure 9-35B, the rear of the hood drops and the front goes up. If there is a height problem at the center edge of the hood, the hood edge height can be adjusted slightly as shown in **Figure 9-36**. Move only the edge of the hood. This method will not work on a plastic hood.

Doors

Doors are complicated assemblies. As shown in **Figure 9-37,** doors consist of the door shell, the door skin, the crash beam, and in most cases, the window frame. The ***door shell*** is the framework that supports all other door components. The ***door skin*** is the outer panel of the door. The ***crash beam*** helps protect occupants in the event of a side impact.

The internal components of a door are bolted, riveted, or slid into part of the door shell. The latch engages the striker to hold the door shut. Hinges allow the door to swing open. The hinges may be welded or bolted to the cowl or door. The door check prevents overextension of the hinges. The window is moved up and down by a manual or power window regulator. The glass moves in run channels. The inner and outer belt moldings seal the glass, keeping out water. Water that leaks past the belt molding will cause the inside of the door to rust. The door handles (inside and outside) and locks (inside and outside) move rods that are connected to the door latch. The door locks may be manual or power. A plastic water shield is glued to the inside of the door frame. The water shield helps keep moisture out of the inside of the door.

To check a door hinge for wear, open the door and try to raise the rear. Play in the door indicates worn hinge bushings. A door cannot be aligned if the bushings are worn.

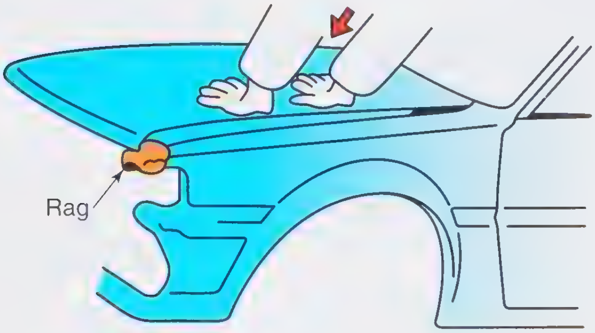


Figure 9-36. *This diagram shows how to lower a hood edge to align with a fender. A block of wood or a rag is used to raise the front of the hood. The technician pushes down at the high edge. A low edge can be raised by positioning the block of wood at the low edge and pushing down on the front of the hood. (Toyota)*

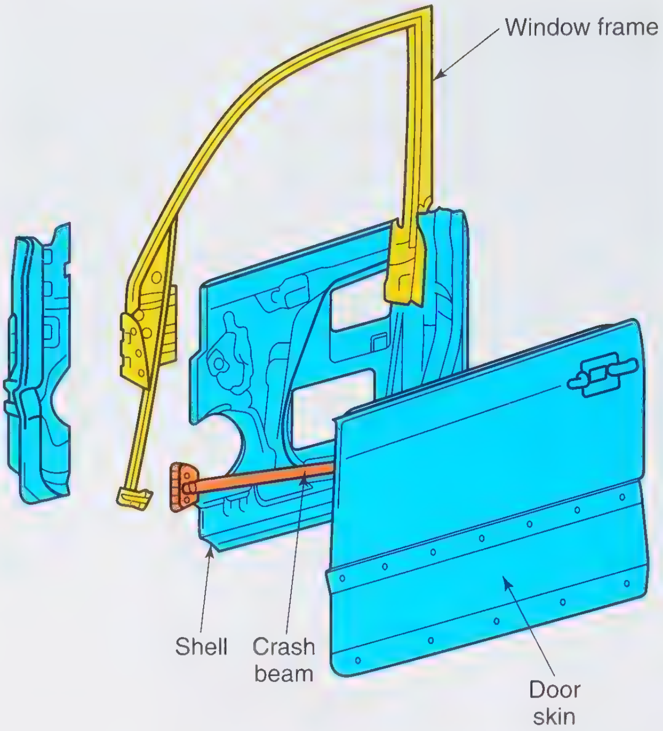


Figure 9-37. *The parts of a door include the door skin, crash beam, window frame, and door shell. (Toyota)*

Removing a Door

Collision impact may damage the latch and striker or misalign them so much that the door cannot be opened normally. If this is the case, there are at least two ways to remove the door. The first option, if the quarter panel or rear door is damaged, is to use a long pry bar. Insert the bar between the door and the pillar; pull on the door handle at the same time as you pry the door open. Another option is to use a cut-off wheel to cut a window in the door skin below the handle. This window gives access to the rods that control door operation. Pull the rods to open the door.

Once the door is open, it can be removed. First, disconnect any electrical wires going to the door. Pull back the rubber cover in between the door and the cowl. Some vehicles have an electrical connector that allows all the wires in the door to be disconnected at once. Pull out the wires from the cowl to see if the vehicle has this type of electrical connector. If there isn't any connector, the wires must be disconnected inside the door and pulled out before the door is removed. To remove the trim panel, search the panel for clips. Usually there are clips around the outside and possibly in the center. Screws are often found around the door handle and arm rest. Remove the screws, pop the clips loose with an upholstery tool, and remove the trim panel. Then remove the plastic water shield. Disconnect the electrical wires and pull them out of the door. If the door has bolted-on hinges, remove the door from the hinges. Leave the hinges attached to the cowl.

To remove doors with welded-on hinges, **Figure 9-38**, use a special tool to remove the spring. Then support the door shell with a floor jack and drive the center pin out of each hinge. The pin in the upper hinge is driven down and the pin in the lower hinge is driven up.

NOTE

To remove damaged hinges, remove the bolts or drill out the welds holding them in place. Some bolted hinges have a bolt that is installed from the inside of the vehicle. In this design, the front door's upper hinge bolt is accessible from under the dashboard.

After the door has been removed from the vehicle, it can be disassembled. Some parts, such as the run channels, glass, and door handles, may be riveted in place. To remove rivets, use a punch to knock out the mandrel in the center of the rivet. Then, using a drill bit that is slightly larger than the hole in the center of the rivet, drill through the hole. This will release the rivet. Remove the run channel from around the window frame. Either unbolt or drill out the rivets holding the window to the regulator. Slide the window out. Remove the regulator, lock latch, and handles.

NOTE

To lower the power window on a used door, hook the leads from a battery charger or a spare battery to the power connectors on the window regulator.

Installing a Door

An empty door shell is lighter and easier to install than an assembled door shell. If hinges are to be replaced, they are installed before the door. The replacement for a welded-on hinge may be a bolt-on hinge. When this is the case, instructions will generally be provided with the replacement hinge. If the replacement hinges are welded on, they are installed by temporarily positioning them with bolts and then fitting the door. Once the alignment is correct, weld on the hinge. With the hinge in place, bolt on the door. For welded-on hinges, push the hinges together and slide the pins in place. Insert the compressed door spring in the slots and release the tool. When installing a used door on a vehicle with the fender removed and that has a latch in place, one technician can position the door in the opening and engage the striker in the latch. This will support the door while the technician bolts or drives a pin.

The alignment checks for a door are shown in **Figure 9-39**. These checks are easier if the striker or

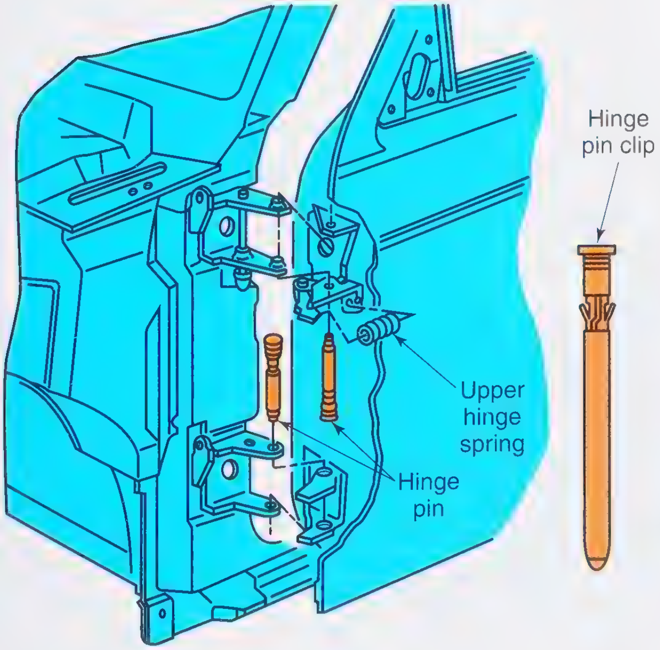


Figure 9-38. *To remove a door with welded-on hinges, first remove the spring with a door spring compressor. Support the rear of the door with a floor jack. Drive the upper hinge pin down and drive the lower hinge pin up.*

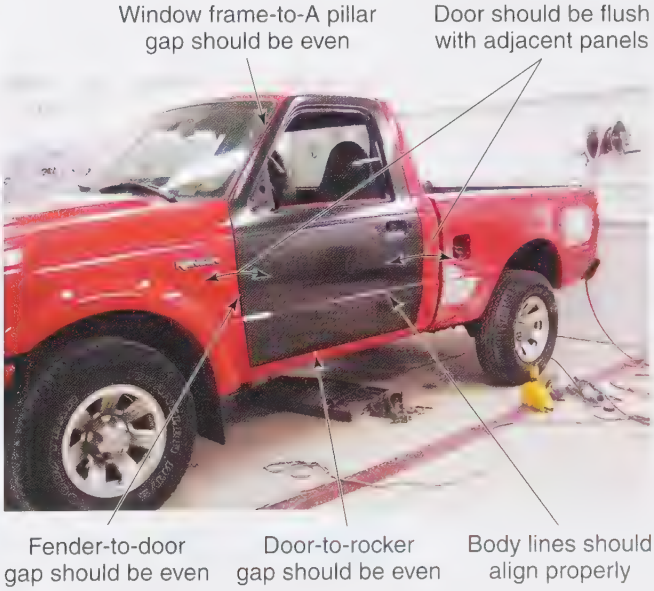

Window frame-to-A pillar gap should be even
Door should be flush with adjacent panels
Fender-to-door gap should be even
Door-to-rocker gap should be even
Body lines should align properly

Figure 9-39. *Alignment checks for a door. The door must be flush or slightly in compared to the fender. The body lines on the fender, door, and cab corner must align and the gap between the window frame and the roof must be even.*

door latch is removed. The first check is made at the bottom of the door. If the gap is even, the door is hanging level. If the gap is too narrow, loosen the door on the hinges and move it up. Do the opposite if the door gap is too wide. If the gap is tapered wide at the front and narrow at the rear, move the top hinge where it is bolted to the cowl forward and the bottom hinge rearward. This will widen the gap at the rear. Do the opposite if the gap is narrow at the front end and wide at the rear. See **Figure 9-40A**.

If the hinges cannot be moved forward or rearward at the fender, try adding a shim between the door and the hinge. See **Figure 9-40B** for hinge movement. When the bottom gap is correct, look at the gap between the window frame and the A-pillar. This gap should be even and flush. Window frame adjustments are shown in **Figure 9-41**. Use a sheet of paper to check for sealing. Close the door on the paper and then pull the paper out. There should be a slight drag. No drag indicates that there is not a proper seal and, therefore, there will be an air leak when the vehicle

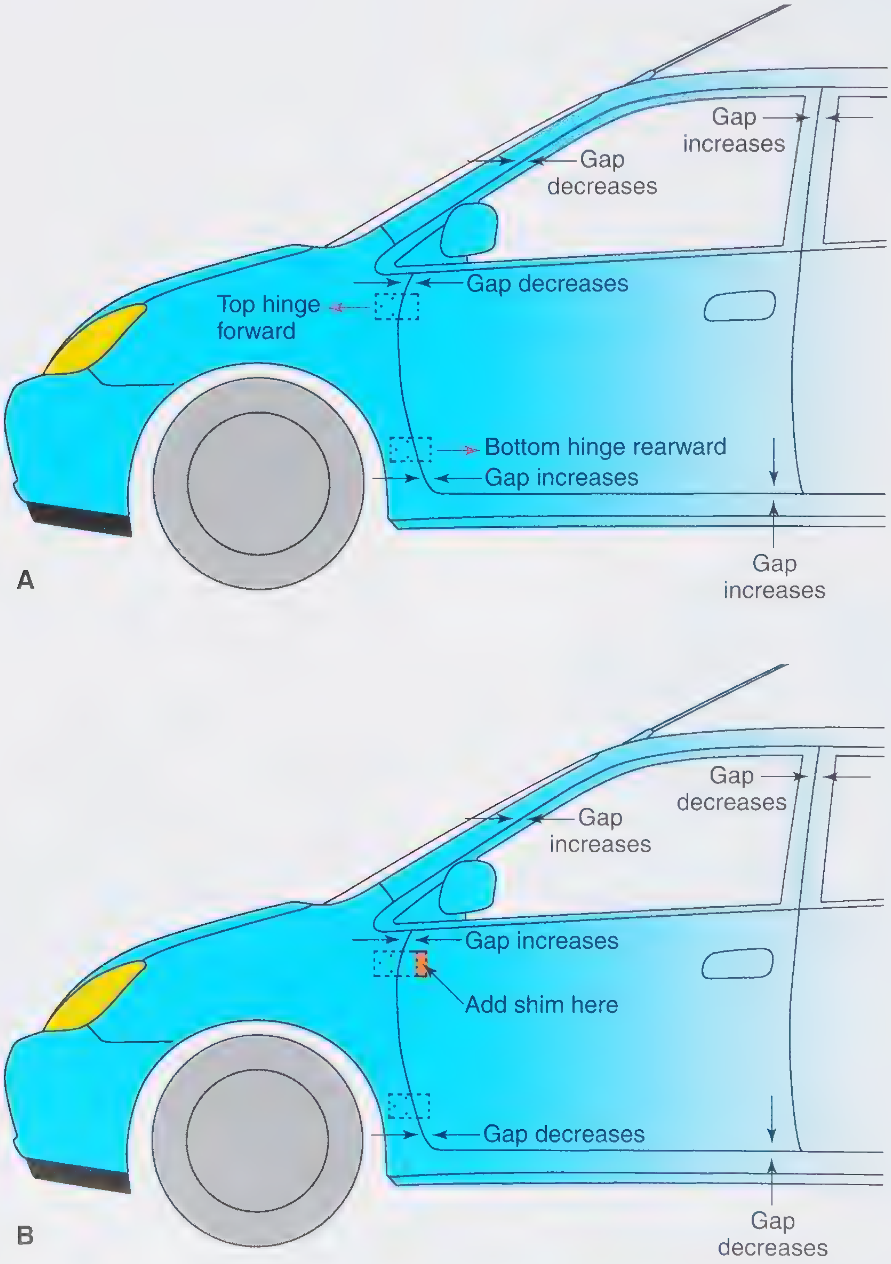

Gap increases
Gap decreases
Gap decreases
Top hinge forward
Bottom hinge rearward
Gap increases
Gap increases
A
Gap decreases
Gap increases
Gap increases
Add shim here
Gap decreases
Gap decreases
B

Figure 9-40. *This diagram shows how hinge movement affects the door gaps. A—Moving the top hinge rearward and the bottom hinge forward. B—Adding a shim between the top hinge and the door causes the opposite effect. A shim at the bottom hinge would raise the rear of the door.*

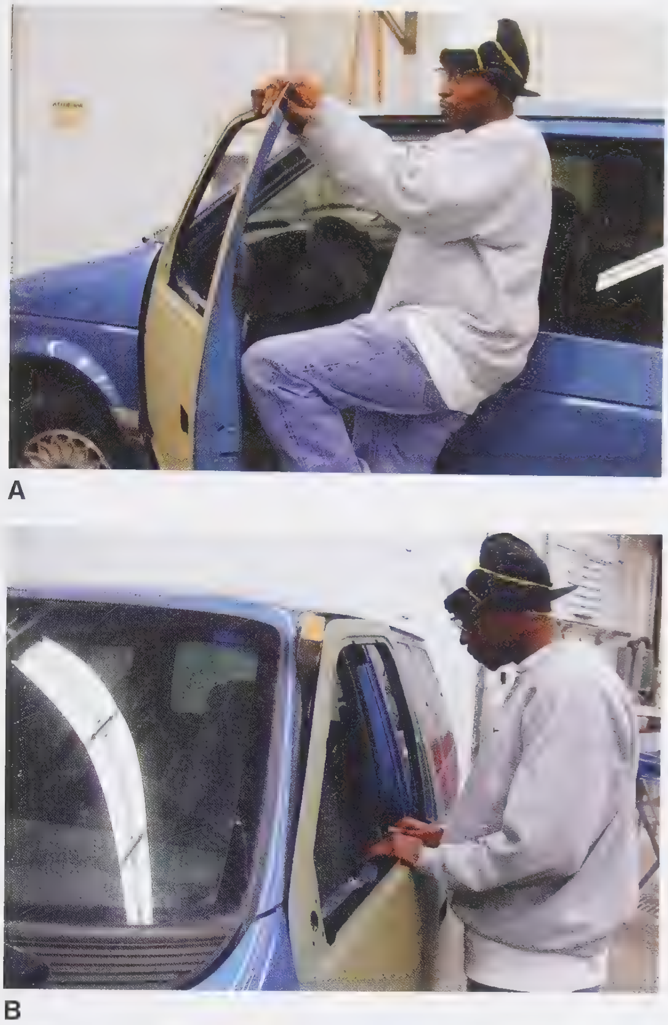


Figure 9-41. *A—Move the window frame in by bracing the lower part of the door and pulling in on the window frame. B—Move the window frame out by placing a block of wood between the window frame and the door opening and pushing in on the lower part of the door.*

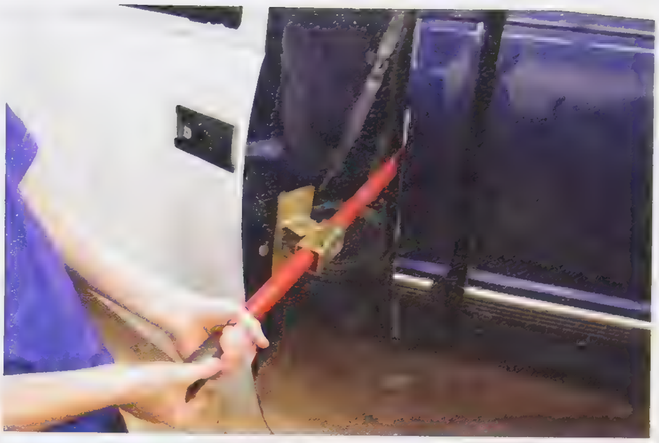


Figure 9-42. *This door has welded-on hinges. The bar is based on the striker and attaches to the latch. The rear of the door can be adjusted up or down with the bar.*

is driven. The last check to make is the gap between the fender and the door. If the door's gap at the bottom is correct, but the gap at the fender is not good, adjust the fender to fit the door. The door should be flush to the adjacent panels and the body lines should align. Doors with welded-on hinges are adjusted with a bar. The door latch and striker must be installed to use this tool. Insert the tool in the latch and hold it onto the striker. Move the door up or down as needed. See **Figure 9-42**. If a bar is not available, a floor jack can be used at the rear of the door. Use a block of wood on the jack saddle to prevent door damage. Jack up the rear of the door to raise the door. To lower the door, pull the rear of the door down.

If the door does not have a window frame, the door should be adjusted with the window in place. The seal between the window glass and the roof's weather strip is critical. Adjust the door so it is flush with the quarter panel and fender. Adjust the window glass for a good seal on the weather strip. If the door cannot be aligned, measure the door opening to see if it is the same as the opening on the other side of the vehicle.

After aligning the door, install the latch, handles, lock, and rods. Check to see if the door opens and shuts properly. The door should shut when it is pushed from a distance of about two feet. It should not hang up as it is opened. Oil the latch and shut the door. If the door is difficult to open or shut, loosen and move the striker. The striker is usually a Torx bolt. See **Figure 9-43**. Moving

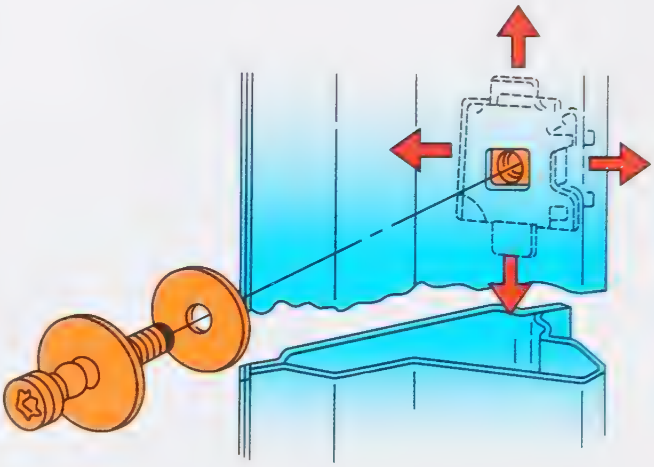


Figure 9-43. *The position of the striker affects the alignment of the closed door. Moving the striker in moves the door inward, and moving the striker out moves the door outward. Similarly, moving the striker up moves the door upward, and moving the striker down moves the door downward.*

it up will bring the door upward. Moving the striker in will move the door inward. Removing a shim will move the striker rearward. When the door is latching properly, install the run channels, glass, and regulator. Check the window for proper operation.

NOTE

If the power window will not go all the way down after the door replacement, check the routing of the wires. The wires may have been routed incorrectly, preventing the window from going down.

Check the operation of the door with all the windows shut, including the window in the replacement door. The door should shut easily. When everything works, install the water seal and the trim panel.

Deck Lid

A rear deck lid is sometimes called a trunk lid. The replacement of a deck lid is similar to the replacement of a hood. Deck lids may be made out of steel or aluminum.

The parts of a deck lid are shown in **Figure 9-44**. The striker and latch may be found on the deck lid and the rear body panel. The hinges are bolted to the lid and are welded or bolted to the rear package shelf. When the latch is released, torque rods or springs pop the lid open and hold it open. A lock releases the latch. There may be a lamp and a remote release. A weather strip between the lid and the body seals the luggage compartment. The height of the deck lid at the rear is adjusted with stops.

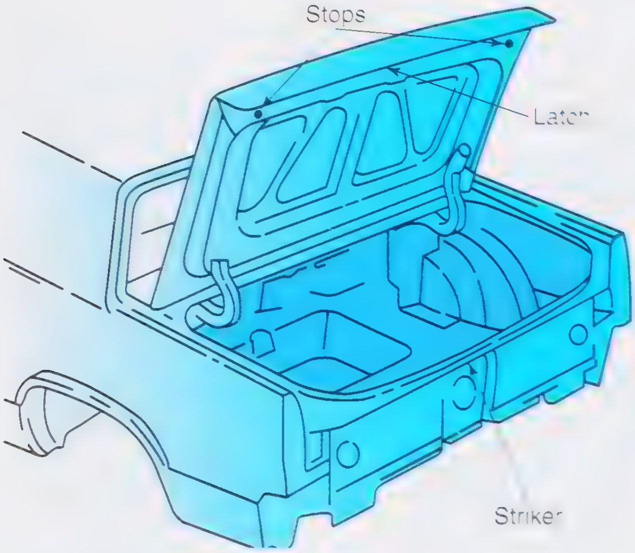


Figure 9-44. *Here is a typical deck lid with hinges. The striker may be on the deck lid or the rear body panel.*

Removing a Deck Lid

A deck lid that is smashed shut can be opened by prying or cutting the lid away from the striker. If the lid has been misaligned by a rear hit, the hinges may be bent. If the front edge of the lid overlaps the rear window, straighten the hinge before removing the lid. Use a ten-pound slide hammer to move the hinge rearward. See **Figure 9-45**. Remove the hinge bolts after all the electrical wires have been disconnected. Because most deck lids are small, this is usually a one-man job. Transfer parts to be used in the new deck lid once the new lid is installed.

Installing a Deck Lid

Bolt the new deck lid in place. Install the electrical connectors, but do not install the latch. This will make the alignment easier. The alignment checks for a deck lid are shown in **Figure 9-46**. Check the gap at the rear window first. If this gap is even, the lid is on straight. Move the lid forward or rearward on the hinges to make this gap even and the correct width. Next check the gap at the quarter panels. This gap should not be tapered and should be the same width on both sides of the vehicle. If the gap is not even on both sides of the vehicle, open the deck lid and move the lid to even the gap.

Finally, check the gap at the rear of the deck lid. It should be even. Occasionally a new or used deck lid or hood needs some minor tweaking to make it fit. If the gap is not even and one side of the deck lid is higher than the other, you can adjust the height by placing a block of wood in between the deck lid and the quarter panel on the low side. Push down on the high side. This will force the high side down and the low side up.

The lid should fit flush. Adjust the stops at the rear to the proper height. If the front of the lid is not at the

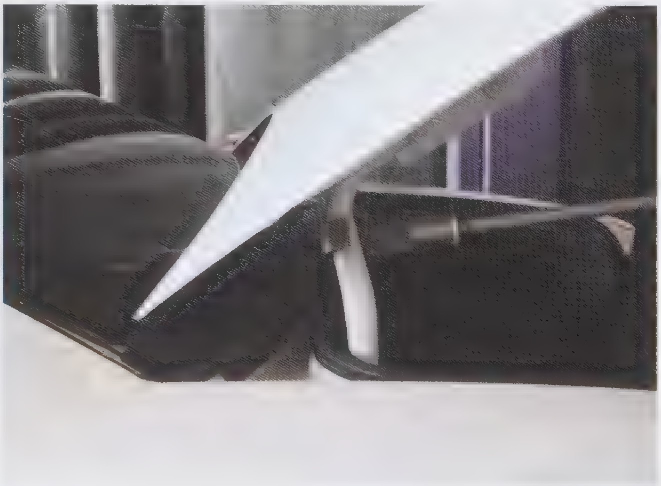


Figure 9-45. *A rear impact on a deck lid may bend the hinge. Move the hinge rearward with a slide hammer.*

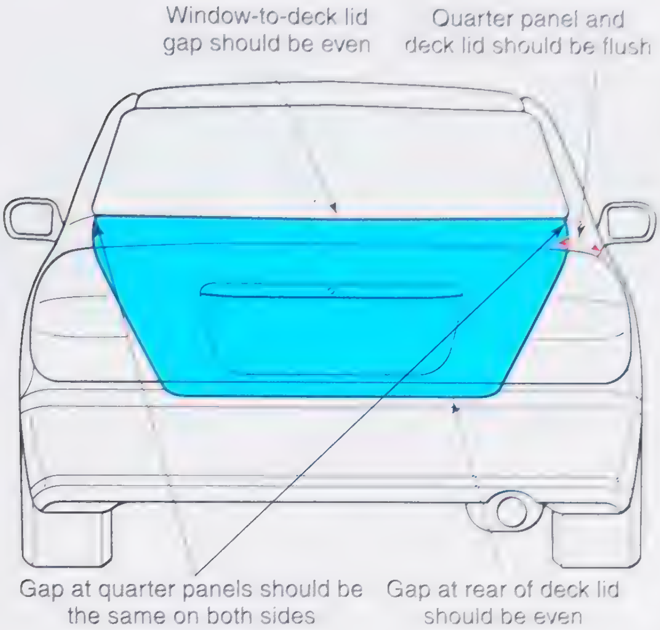

Window-to-deck lid gap should be even
Quarter panel and deck lid should be flush
Gap at quarter panels should be the same on both sides
Gap at rear of deck lid should be even

Figure 9-46. *These are the alignment checks for a deck lid. (Toyota)*

right height, raise or lower the hinge. If the hinge cannot be raised, install a shim between the lid and the hinge.

With the deck lid aligned properly, install the latch. The lid should shut when dropped from a height of approximately one foot. If the deck lid will not shut properly, make sure the striker is engaging the latch. If the striker is on the deck lid, raise the latch. If the latch is on the deck lid, lower the latch. If the stops are adjustable, move the stops down. If the deck lid is loose when closed, the latch should be adjusted. If the striker is on the deck lid, lower the latch. If the latch is on the deck lid, raise the latch. If the stops are adjustable, raise the stops.

Check the seal between the deck lid and the weather stripping with a piece of paper. If there is a water leak, the fastest way to find it is to put a technician in the trunk with a flashlight. Shut the lid and spray water on the vehicle. The technician inside the trunk looks for the location where the water is leaking. The leak will be the highest spot where water is seen. If the water is leaking from a gap between the weather strip and the lid, tap up on the lip that supports the weather strip. This action should close the gap.

Rear Hatch

A rear hatch can be made out of steel or plastic. The rear hatch will have a window. A rear hatch and related parts are shown in **Figure 9-47**. The hatch has simple bolt-on hinges. Lid struts open the lid when the latch is released. A striker holds the hatch shut. A weather strip seals the opening. There may be a license plate lamp and brackets. There may also be a windshield wiper and motor. Stops set the rear height of the hatch.

Removing a Rear Hatch

If necessary, pry or cut open a damaged hatch. Disconnect any electrical wires after removing the trim panel. Removing a hatch is a two-person operation. Position a technician at either hinge. Unbolt the hatch and remove it. Finally, remove the glass from the hatch and unbolt the latch or striker.

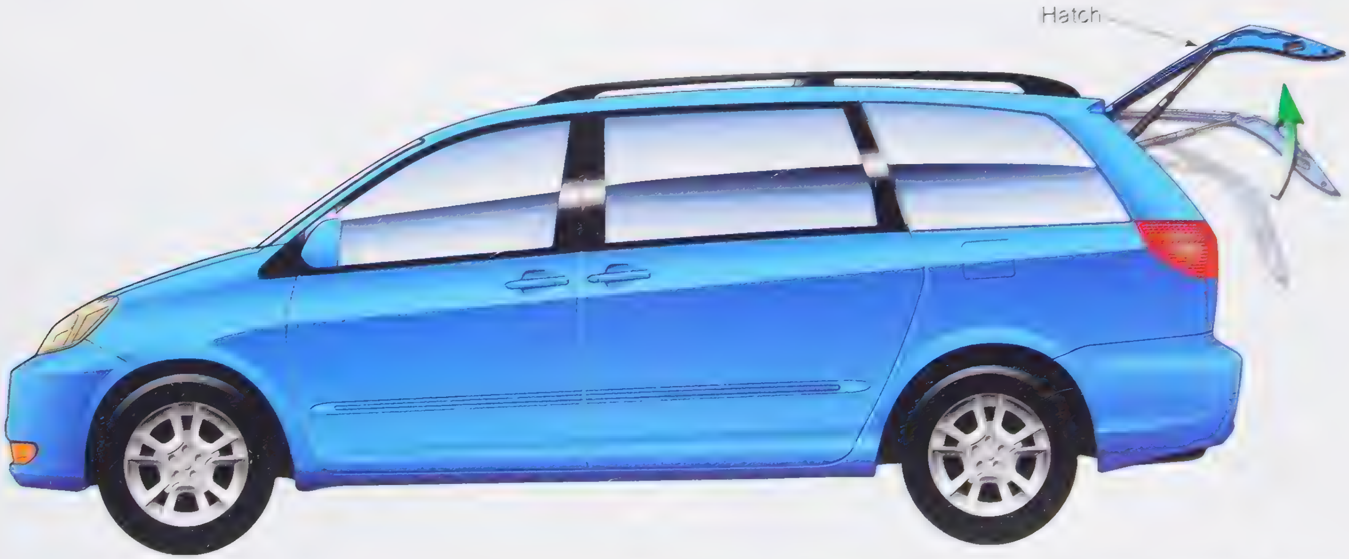


Figure 9-47. *This drawing shows a typical rear hatch. The hatch assembly consists of a rear window, hinges, license plate lamp, interior trim panel, and striker. Some hatches have a rear window wiper and a weather strip. (Toyota)*

Installing a Rear Hatch

The new hatch should be painted underneath and around the window opening before installation. Transfer the parts to the new hatch. Bolt the hatch in place.

The alignment checks for a hatch are shown in **Figure 9-48**. A hatch has a minimal amount of adjustment. Check the gap between the hatch and the roof first. This gap should be even. Adjust the hatch rearward if the lid hits the roof. If the gap is tapered, adjust the hatch as needed. The gap between the hatch and quarter panels should be even and uniform from side to side. Next, check the gap at the rear body panel or bumper. It should also be even. If the hatch is not flush to the body, adjust the stops. Check the hatch for a proper seal using a piece of paper. Place the paper between the hatch and the weather strip, close the hatch on the paper, and then pull the paper out. There should be a slight drag. No drag indicates that there is not a proper seal and, therefore, there will be an air leak.

Sliding Door

Sliding doors are found on minivans. They may be made of steel or plastic. They usually have a window. A sliding door is shown in **Figure 9-49**. The sliding door moves on upper and lower rollers. There may be two latches, front and rear. The latches are operated by rods connected to handles. Some sliding doors have a remote opening feature. Electrical connections are maintained by contacts rather than wires. Like other doors, sliding doors have weather strips and strikers.

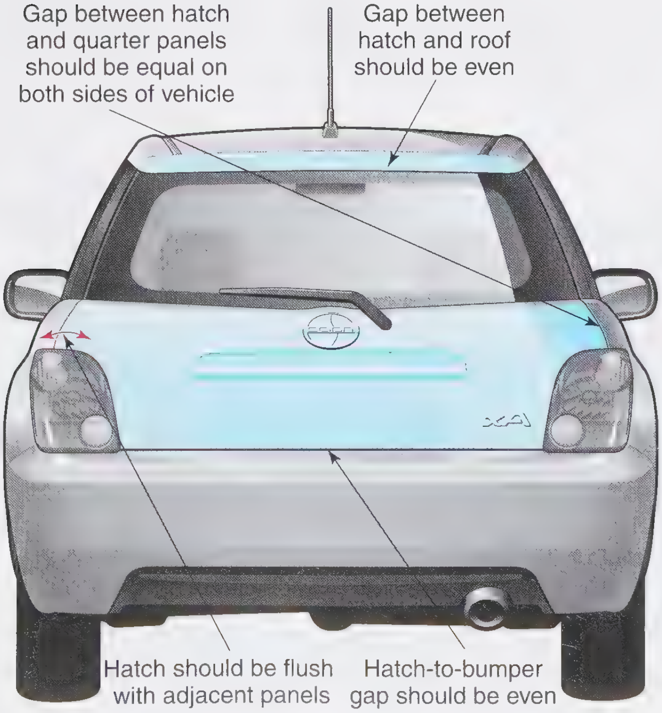

Gap between hatch and quarter panels should be equal on both sides of vehicle
Gap between hatch and roof should be even
Hatch should be flush with adjacent panels
Hatch-to-bumper gap should be even

Figure 9-48. *This illustration shows the alignment checks for a rear hatch. (Toyota)*

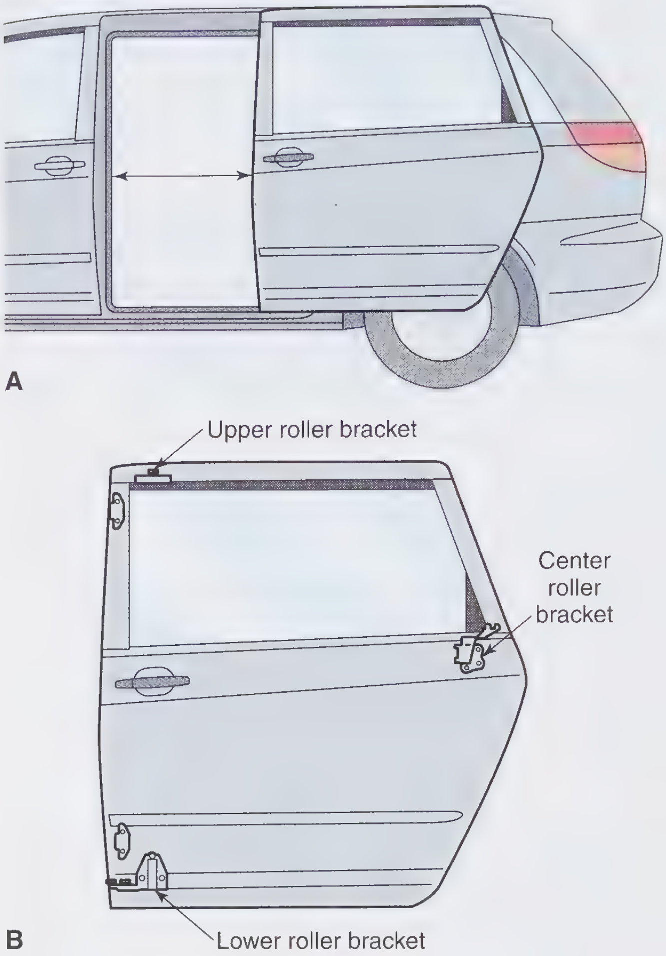

A
Upper roller bracket
Center roller bracket
B
Lower roller bracket

Figure 9–49. *A sliding door is common on minivans. B—Sliding door showing (Toyota)*

Removing a Sliding Door

A sliding door is relatively simple to remove from the vehicle. Either pry or cut open the damaged door if it does not open easily. Then, unbolt the upper and lower rollers and remove the door. Mark the location of the strikers and then remove the strikers from the body of the van. Remove the latch rods, glass, and connectors.

Installing a Sliding Door

Paint the inside of the door and glass area before installing any parts. Then install the latch, rods, glass, and connectors on the replacement door. Bolt the new sliding door onto the rollers.

With two or three strikers and two or three roller attachment points, a sliding door has a considerable amount of adjustment. **Figure 9-50** shows alignment

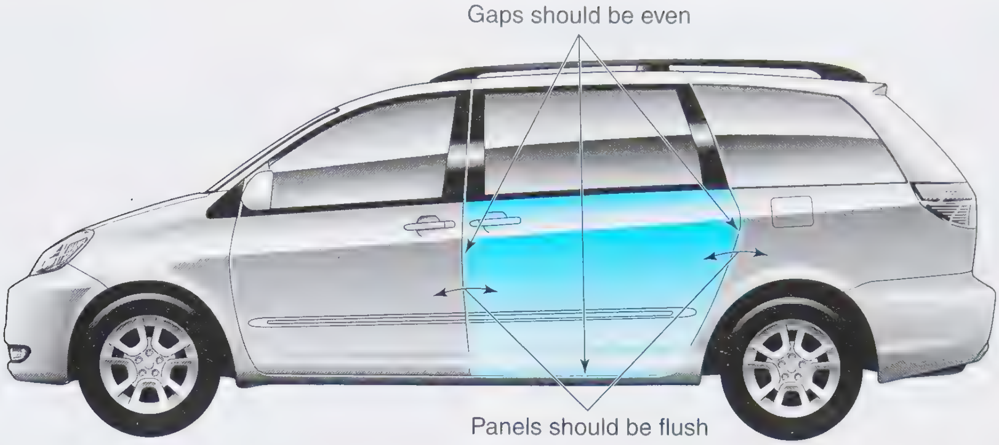


Figure 9-50. *Alignment checks for a sliding door. Adjustments to the upper, center, and lower roller brackets are used to align the sliding door. (Toyota)*

checks on a sliding door. As with other doors, check the door-to-rocker gap first. Move the roller brackets up or down as needed to achieve the proper gap. Check the gap along the top of the door. If the rocker panel gap is even, this gap should also be even. Make sure the sliding door is flush with the surrounding panels. If necessary, adjust the roller brackets to make the sliding door flush. Now install the strikers in their former locations. Slide the door to close it. It should glide shut. If the door does not close easily, oil the rollers and the latches. Check the fit at the rear of the door. The door should be flush with the quarter panel. Move the striker in if the door is positioned out or move the striker out if the door is pointing inward. If the door is too low, raise the striker. Check the fit at the front of the door. Adjust the striker for a flush fit. Finally, check the height and adjust if necessary.

Pickup Bed

Pickup truck beds are made out of steel. The parts of a pickup truck bed are shown in **Figure 9-51**. The bed has one or two gas cap doors, taillights, and a tailgate. Some beds have removable rear fenders.

Removing a Pickup Bed

The first step in removing a pickup bed is to remove the tailgate. Most tailgates do not have hinges. Instead, a tailgate has a knob or holder at each end. If the knobs are on the tailgate, they fit into holders mounted to the bedside. If the knobs are located on the bedsides, the holders are on the tailgate. Open the tailgate and remove the retainer bars or cables. With the retainer bars or cables removed, the tailgate can be opened to an angle greater than 90° with the side of the bed. On most trucks, the holder on the right side of the vehicle is notched so that when the retainers are removed and the tailgate is lowered, the knob can slip out of the notch in the holder. Some trucks do not have a notch in the holder. On these trucks the holder must be unbolted from the bedside. After lowering the tailgate to the correct position, it can be removed. See **Figure 9-52**.

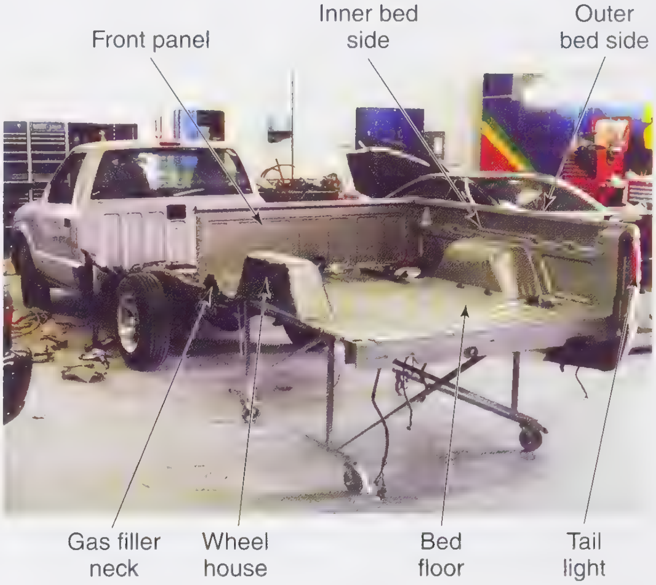


Figure 9-51. *This pickup truck bed has been removed for bed side replacement. The tailgate has been removed along with the left bed side. The bed consists of bed floor, front panel, wheel houses, and inner and outer bed sides.*

After removing the tailgate, disconnect the taillights. If the rear bumper is in the way, remove it. Disconnect the fuel filler neck.

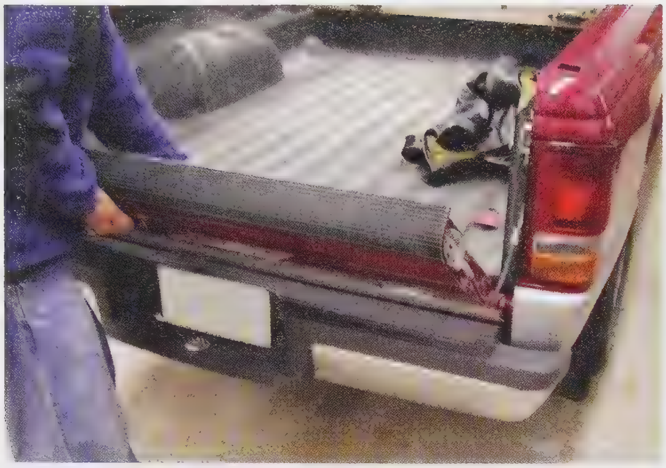


Figure 9-52. *This technician has left the cables on the tailgate while aligning the holder and knob for removal.*

Decide on a place to set the bed before removing it from the vehicle. Then, unbolt the bed from the frame. The bolts may be rusty and difficult to reach. When the bed is loose, position a technician at each corner and lift the bed off the frame.

NOTE

Some beds are held in position with stove bolts, which have a square section under their head that fits into a square hole in the bed. These bolts will sometimes turn as their nuts are removed. If this occurs, grip the heads with locking pliers or grind off the heads to facilitate removal.

Installing a Pickup Bed

Set the new bed in place on the vehicle. Be careful not to hit the back of the cab. Line up all the bolt holes before tightening any bolts. When all of the bolts are in place, check the alignment.

Bed position can be moved from side to side or front to rear. Height is adjusted either by using shims between the frame and the bed or by bending the frame. The alignment checks are shown in **Figure 9-53**. The gap between the cab and the bed should be equal side to side. The fastest way to measure this gap is with your fingers as shown in **Figure 9-54**. Adjust the bed to make the gaps equal. Next, sight down both sides of the truck to see that the bed is flush with the cab. Move the bed over if it is not flush. Check for level between the cab and the bed after the tailgate is installed. **Figure 9-55** shows how to accomplish this task. A slight difference in height can be corrected with shims. Insert a shim between the bed and frame to raise a low area. Once the bed is aligned, tighten the bolts. Install the taillights and fuel filler neck.

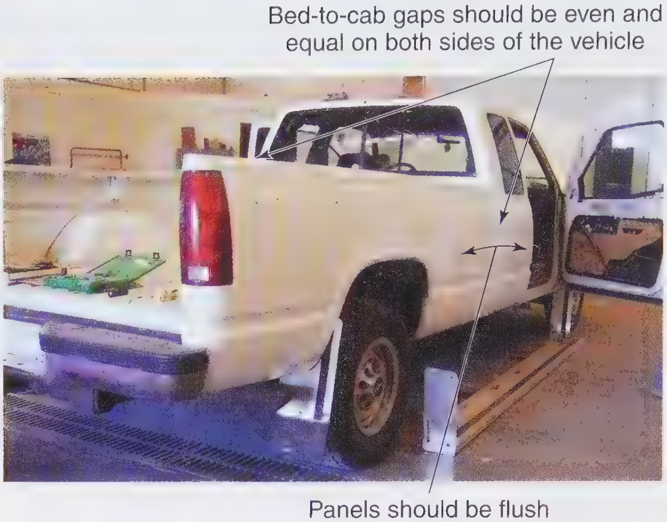

Bed-to-cab gaps should be even and equal on both sides of the vehicle
Panels should be flush

Figure 9-53. *The alignment of the bed and cab is checked at the gap. The gap should be uniform.*

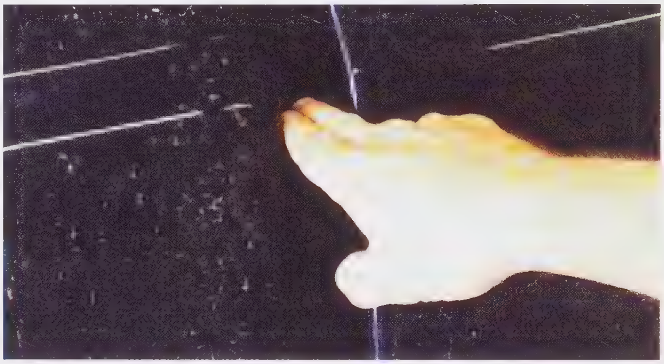


Figure 9-54. *Fingers inserted in the bed to cab gap is a quick way to check bed alignment.*

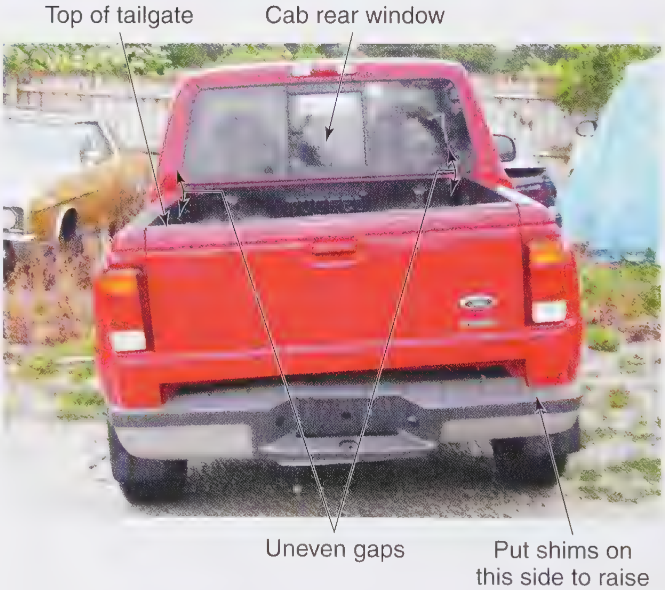


Figure 9-55. *Check that the tailgate is level with the rear window. Raise the low side with shims.*

Summary

- Replacement bolted parts can be obtained from three sources: original equipment manufacturers, salvaged vehicles, and aftermarket suppliers.
- Be alert for hidden damage, which is evident only after parts have been removed.
- When replacing several panels on the side of a vehicle, always position the panel with the least amount of adjustment first.
- Movable parts should be adjusted so they function properly and are aligned correctly with other panels.
- Nonmovable parts should be positioned so the panel gaps are correct.
- All panel gaps should be uniform in width. Tapered panel gaps are a sign of misalignment and a poor-quality repair.
- All parts installed should be level relative to the vehicle.
- Flush means that two or more adjacent panels are at the same surface level.
- One goal in removing any damaged part is to avoid creating additional damage.
- Header panel alignment is dependent on the position of the fenders and radiator support. These components must be properly aligned before aligning the header panel.
- If you have difficulty getting a fender to fit properly, make sure the tab, the hidden nut, or the bolt it attaches to is in the proper place. Also check the unibody or frame for damage.
- When installing a hood latch, position the latch so the striker hits in the center of the latch. A misaligned latch will pull the hood to one side.
- The alignment checks for a door are easier if the striker or door latch is removed.
- Pickup bed position can be moved side to side or front to rear. Height is adjusted using shims between the frame and the bed or by bending the frame.

Review Questions

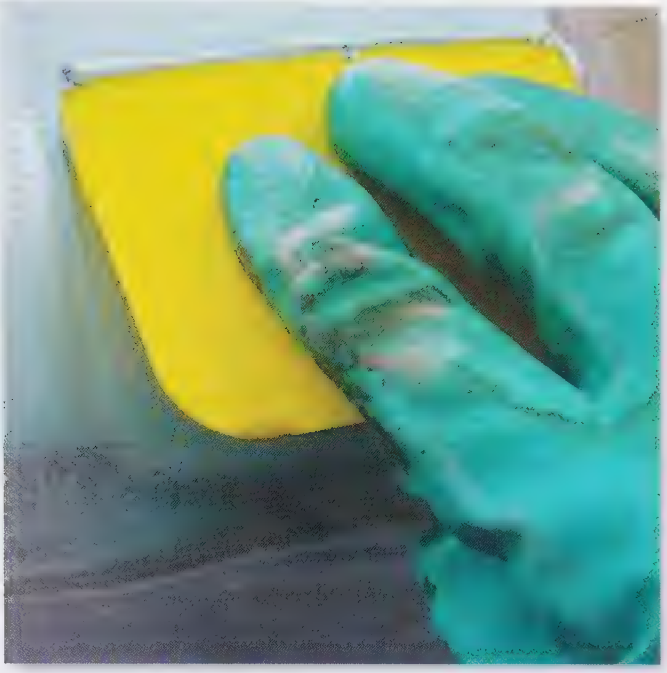
Please do not write in this textbook. Place your answers on a separate sheet of paper.

1. List the three sources of replacement parts.
2. Explain how to use a finger to check panel gap width.
3. When checking a bumper for level, the technician should use the hood as a reference. True or False?
4. When two or more adjacent panels are at the same surface level, they are said to be ______.
5. Bumper bolts have a(n) ______ shank.
6. Plastic bumper covers are found on all vehicles. True or False?
7. List the two types of header panels.
8. A skin-type fender is found on a vehicle that has a front inner structure that is welded together. True or False?
9. The first check of fender alignment is the fender-to-______ gap.
10. A fender-to-hood gap is too narrow. There isn't any more adjustment in the fender or hood. Explain what to do to make the gap wider.
11. A smashed hood does not open when the hood release cable is pulled. Explain how the hood can be opened.
12. A hood is to be checked for alignment. The first gap to check is at the ______.
13. The hood is too high at the rear. The hood hinges are bolted to the fender. What should be done?
14. The first check for door alignment is made at the ______.
15. A door is not level at the rocker panel. The gap at the rear is too wide. What should be done?
16. A deck lid is loose when closed. The striker is on the deck lid. The latch should be ______.
17. Explain how to check a rear hatch for a proper seal.
18. Sliding doors can have ______ strikers.
19. Explain how to remove a pickup truck bed.
20. Shims inserted between a bed and a frame will ______ the bed.

ASE-Type Questions

1. Technician A says replacement panels may be available from aftermarket suppliers. Technician B says availability is a key issue when deciding on a part source. Who is right?
   (A) A only.
   (B) B only.
   (C) Both A and B.
   (D) Neither A nor B.
2. All of the following are movable parts EXCEPT:
   (A) deck lids.
   (B) hatches.
   (C) header panels.
   (D) hoods.
3. Wind noise was discovered after a door was replaced. Technician A wants to check the door-to-fender for flush. Technician B wants to check the door-to-A pillar for fit. Who is right?
   (A) A only.
   (B) B only.
   (C) Both A and B.
   (D) Neither A nor B.

4. An aftermarket bumper has the wrong size holes for the mounting tabs. Technician A says that the holes should be enlarged to accept the tabs. Technician B says the tabs should be trimmed to fit the holes. Who is right?
   (A) A only.
   (B) B only.
   (C) Both A and B.
   (D) Neither A nor B.
5. A fender-to-door gap is wide at the bottom and tight at the top. This problem would indicate that the ______.
   (A) rear of the fender is too high
   (B) front of the fender is too low
   (C) front of the fender is too high
   (D) rear of the fender is too low
6. A hood jumps to the left when it is opened. Technician A wants to move the latch to the left. Technician B wants to move the latch to the right. Who is right?
   (A) A only.
   (B) B only.
   (C) Both A and B.
   (D) Neither A nor B.
7. A replacement hood does not touch the hood stops. What should be done to solve this problem?
   (A) Lower the latch.
   (B) Lower the striker.
   (C) Lower the stops.
   (D) Lower the hinge.
8. Technician A says that window regulators may be manual or power. Technician B says that window regulators are always spot welded in place. Who is right?
   (A) A only.
   (B) B only.
   (C) Both A and B.
   (D) Neither A nor B.
9. A door has hinges that are welded to the cowl and the door. To remove the door, the center pin in the hinges should be ______.
   (A) cut with a cut-off tool
   (B) cut with a plasma cutter
   (C) drilled out
   (D) driven out
10. Door handle rivets need to be removed. Technician A wants to drill out the rivets. Technician B wants to grind off the rivet heads. Who is right?
    (A) A only.
    (B) B only.
    (C) Both A and B.
    (D) Neither A nor B.
11. A replacement door is being checked for fit. Technician A wants to check the door-to-quarter panel gap first. Technician B wants to check the door-to-A pillar gap first. Who is right?
    (A) A only.
    (B) B only.
    (C) Both A and B.
    (D) Neither A nor B.
12. A door without a window frame needs to be adjusted. Technician A wants to adjust the door with the window installed. Technician B wants to adjust the door with the window removed. Who is right?
    (A) A only.
    (B) B only.
    (C) Both A and B.
    (D) Neither A nor B.
13. A misaligned deck lid overlaps the rear window. Before removing the deck lid, the hinge should be ______.
    (A) removed
    (B) straightened
    (C) adjusted
    (D) replaced
14. A rear hatch is being adjusted. Technician A believes that a rear hatch has only a small amount of adjustment. Technician B believes that the latch or striker should be removed. Who is right?
    (A) A only.
    (B) B only.
    (C) Both A and B.
    (D) Neither A nor B.
15. A pickup truck bed needs to be removed. All of the following should be removed EXCEPT:
    (A) the rear bumper.
    (B) the bed side.
    (C) the taillights.
    (D) the gas filler neck.



Chapter 10

Welded and Bonded Nonstructural Panel Replacement

Objectives

After studying this chapter, you will be able to:

- List the steps involved in replacing welded and bonded nonstructural panels.
- Analyze damage that requires panel replacement.
- Locate and remove spot welds.
- Describe various panel joining techniques.
- Explain the procedures for replacing specific welded and bonded nonstructural panels.

Technical Terms

bonding
butt joint
dressing welds
finishing
flange joint
full panel replacement
hole saw
joining
joint
lap joint
rough cutting
semi-butt joint
sleeve joint
splice replacement
spot welds
structural adhesive
weld bonding
weld-through primer
working time

Introduction

This chapter explains how to replace welded or bonded nonstructural panels that have been damaged. These panels can be replaced in one of two ways: full panel replacement or splice replacement. In a ***full panel replacement***, the entire damaged panel is removed from the vehicle at the factory seams and a replacement panel is welded or bonded in place. Many times, due to vehicle construction or the degree of damage, full panel replacement is not practical. In a ***splice replacement***, or a splice, the damaged portion of a panel is removed and only a portion of the full replacement panel is installed. A splice replacement will save repair time. When proper procedures are followed, a splice is an acceptable repair method.

NOTE

When replacing multiple welded or bonded panels, such as two door skins or a door skin and a quarter panel, align and weld or bond all panels at once rather than individually. When installing a door skin and straightening a quarter panel, install the door skin first and then repair the quarter panel so the quarter matches the door.

Welded and Bonded Nonstructural Panel Replacement Steps

The general steps for replacing damaged welded or bonded nonstructural panels include:

1. Reading the estimate.
2. Analyzing the damage.
3. Planning the repair.
4. Accessing the damage.
5. Rough cutting.
6. Final cutting.
7. Preparing the panels for installation.
8. Fitting the replacement panel in place.
9. Joining the replacement panel to the vehicle.
10. Finishing the repair areas.

Each of these steps will be discussed in detail in the following sections. These steps apply to both full panel replacement and splice replacement.

Reading the Estimate

The first step in any repair is to read the estimate or repair order. Study each line of the estimate. Find out which parts will be repaired and which will be replaced. If parts will be replaced, determine if the parts will be new OEM, new aftermarket, or used. In many repairs, new replacement panels will be installed. This is because considerable effort is required to remove a used panel from a vehicle without damaging the panel. Nevertheless, used quarter panels may be installed to reduce the overall cost of the repair.

Analyzing the Damage

Damage analysis is an extremely important step in the panel replacement process. All damage must be identified before replacing panels. Because most vehicle panels are connected, damage to one panel may extend into adjacent panels. Before planning the repair, all damage, including hidden damage, must be identified. A rear impact on a unibody vehicle may shorten the rear frame rail. A rear impact on a full-frame vehicle may shorten the frame. The shortening of a frame rail or frame can buckle a quarter panel or bed side. See **Figure 10-1**.

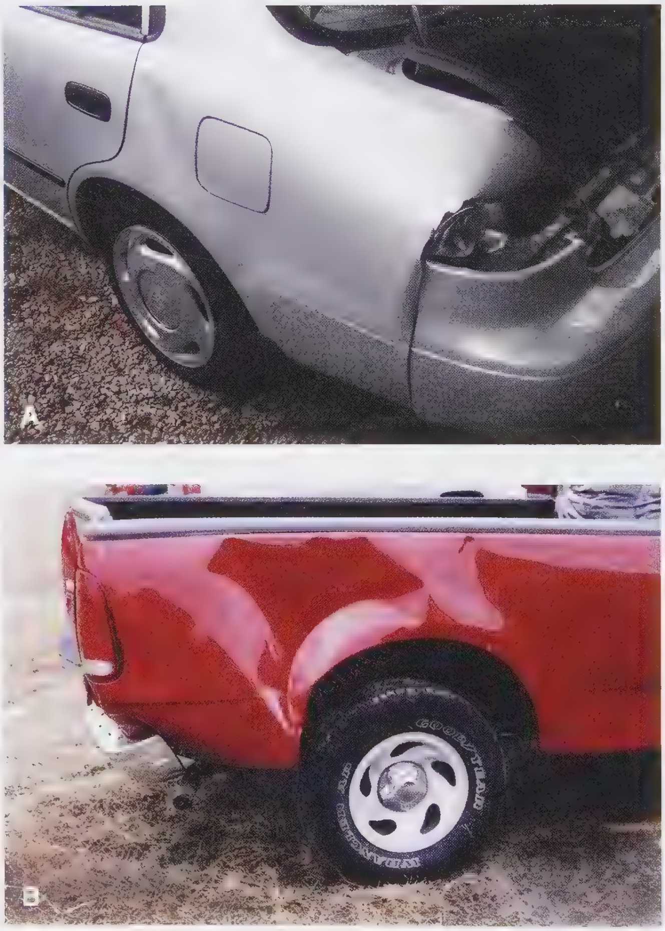


Figure 10-1. *A—A rear impact shortened the left rear unirail and damaged the quarter panel on this vehicle. B—The frame must be repaired on this truck before the bed side is replaced.*

The frame damage must be straightened before the quarter panel or bed side can be replaced. A replacement panel, which is the proper length, would not fit a vehicle with a damaged unibody or frame. Carefully inspect the entire vehicle before planning the repair. Compare the estimate or repair order to the damaged vehicle. Look for discrepancies between the information included on the estimate and the actual damage on the vehicle.

Planning the Repair

Careful planning is a must when replacing welded or bonded panels. Think through all the steps in the repair process during planning stage. Some questions to ask during the planning stage include:

- What type of replacement does the vehicle manufacturer recommend (splice or full replacement)?
- What types of tools are needed for the repair?
- Should the damage part be straightened by pulling before removal?
- Which parts must be removed for access to the damaged or panel joints?
- Where will the removed parts be stored during the repair?
- What type of joints will be used to join the panels?
- Will the replacement panel be installed with adhesives or welded?
- If the replacement part is welded, is the back side accessible for rust proofing after installation?

The area where the vehicle and the replacement part meet is called the ***joint***. The common types of joints used in panel replacement include the butt joint, sleeve joint, flange joint, lap joint, and semi-butt joint. See **Figure 10-2**.

In a ***butt joint***, the panels are aligned so the width of the gap between them is equal to the thickness of each panel. This joint can be welded with a series of spot welds or stitch welds. A butt joint should only be made on crowned panels that are less than 6" wide. These panels have enough strength to resist warping. An example would be a window frame on a door skin replacement.

A ***sleeve joint*** involves using a 2"-wide sleeve that is the same length as the joint. The sleeve is slipped under the two panels. The panels are aligned as in a butt joint, but the width of the joint should be twice the thickness of each panel. This will allow for a good weld on the sleeve and the panels. Stitch welds are made between the two panels. The sleeve is also plug welded to each panel. A plug weld is placed approximately every 2" along the joint. A sleeve joint is commonly used along the sail panel joint during quarter panel replacement.

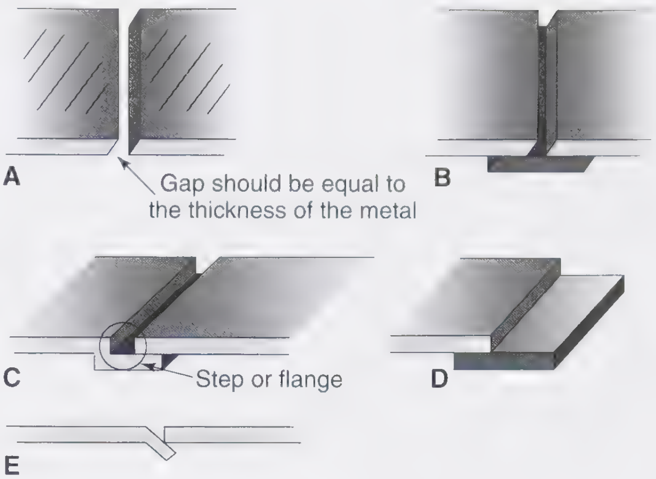


Figure 10-2. *Here are the types of joints used in nonstructural panel replacement. A—In a butt joint, the panels are aligned so that a gap the thickness of the metal separates them. B—In a sleeve, a 2" piece of properly contoured metal is inserted under the weld joint. C–In a step or flange joint, an indentation is made in one panel and the other panel fits in the indentation. D—In a lap joint, one panel is on top of another. E—In a semi-butt joint, one panel is bent so the other panel rests on the bend.*

A ***flange joint*** has a step formed in one of the panels by a flange tool. The step allows the replacement panel to make a flush fit with the existing panel. The flange also stiffens the panel, allowing this joint to be used on long, low-crown panels. There should be a gap of approximately 1/4" between the shoulder of the flange and the edge of the replacement panel. Stitch welds are made along the joint between the shoulder and the replacement panel. This type of joint is used in quarter panel replacement.

A ***lap joint*** is one of the simplest to make. One panel is placed on top of the other and stitch welds are made at edge of the top panel or plug welds are made in the top panel. In a lap joint, the top panel is not flush with the bottom panel. The weld can be ground down and the difference in height can be hidden with tapered body filler. The lap joint stitch weld can be used on window frames. The lap joint plug weld is used on quarter panel replacement at the outer wheel house.

The ***semi-butt joint*** is used when the flange tool cannot reach inside a panel to make a step. Instead, a spoon is inserted and a body hammer is used to bend the metal down. The gap, about the thickness of one of the panels, is stitch welded. This joint can be used on quarter panels near the deck lid opening.

During the planning stage, it is important that you determine the type of joint that will be made. The type of joint will dictate how the panels are final cut.

WORKING SMART

Always plan carefully before making cuts on the damaged panel or the replacement panel. Once a panel is cut, the repair must be made to accommodate the cut.

Accessing the Damage

Bolted or glued-on parts or damage may block access to panel edges. The obstructing parts must be removed for access and reinstalled after the replacement is completed. Damage that extends into adjacent parts that are welded together should be pulled or pushed back in place before removing the damaged panel.

Removal of an obstructing part during quarter panel replacement is shown in **Figure 10-3**. The ground effects on this vehicle block access to the spot welds that hold the quarter panel in place. Some parts that have been removed already include the rear bumper assembly and the left taillight. Other parts that must be removed include the back glass and quarter glass. If the deck lid is in the way, it must also be removed. However, in most cases it can be left in place. To prevent excess work, do not remove more panels than necessary. Store the parts that have been removed out of the way. Keep all fasteners in labeled plastic bags. Tape the bags containing the fasteners to the corresponding parts so they do not get separated. Keep all the parts for the vehicle together.

NOTE

You may be working on more than one vehicle at a time, so be sure to keep the parts for each vehicle separate.

During a collision, the impact force spreads through the vehicle's structure. If a panel is damaged enough to require replacement, the adjacent welded-on panels are often damaged also. Even though a damaged welded-on panel will be replaced, the damage should be pulled out if it extends into adjacent, welded-on panels.

Lateral force on a quarter panel or longitudinal force on a rear bumper may buckle the quarter panel and damage the outer and inner wheel houses. Pulling on the quarter panel or rear unirail will rarely correct significant damage to the outer and inner wheel houses. Additional pulls may be required after the damaged quarter panel is removed. In most cases, the damaged outer panel is quickly cut off to allow better access to the underlying panel. A pull connected directly to the underlying damaged panel is the most effective way to remove the damage. **Figure 10-4** shows a pull on a wheel house.

Rough Cutting

In ***rough cutting***, the damaged panel is removed from the vehicle. If the replacement will be a splice, rough cutting is an approximation, leaving excess material in place rather than cutting to exact dimensions. The replacement panel cannot be test fitted to the vehicle until the damaged panel is removed, and the exact location of the final cuts cannot be determined until the replacement panel is test fitted. If a full panel replacement is made, rough cutting is not normally required because the joint locations are already determined.

Rough cutting also includes preparing the replacement panel. If the replacement panel is new. rough cutting involves cutting the panel approximately 1"–2" longer than required. A used replacement panel often requires the removal of the spot welds that hold it in place. A used replacement part must be removed carefully so it is not damaged.

Welded-on panels are removed by locating and removing the spot welds, cutting any adhesives or sealer, and cutting the panel. Mark the splice joint location if the

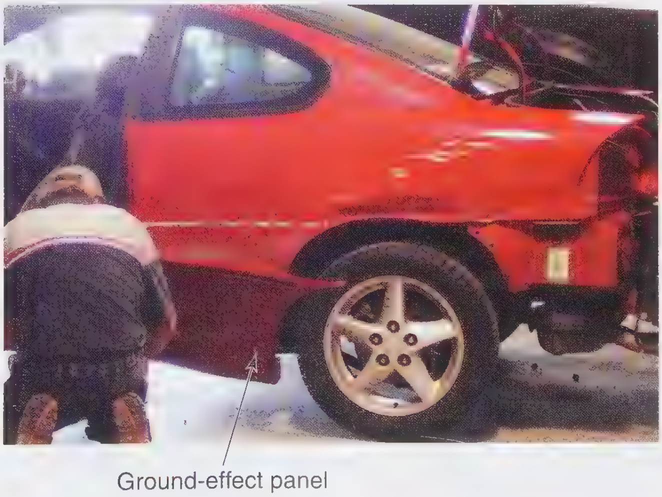


Figure 10-3. *This technician is removing ground effects in preparation for quarter panel replacement.*

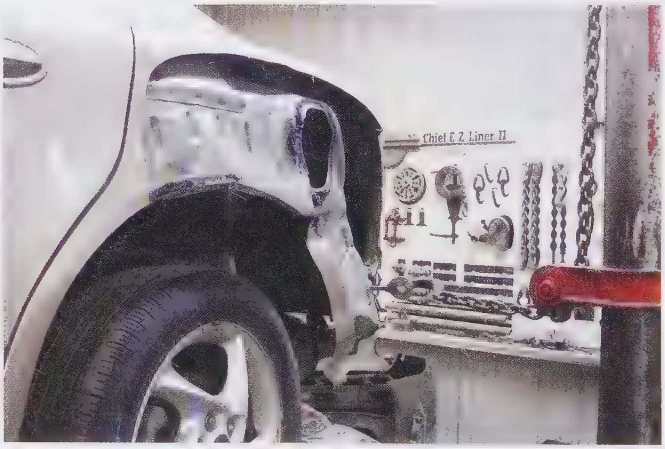


Figure 10-4. *A quick cut has been made on this quarter panel. A direct pull on the damaged wheel house will align the attached panels.*

panel will be spliced. Cut the panel so that at least 2" of metal beyond what is required remains. The cut location is marked with masking tape, **Figure 10-5**. Write on the masking tape to make sure there is no doubt about which side of the tape to cut. Cut on the line with a cutoff tool, air saw or hack saw. If you are using a cutoff tool, move the tool so the spinning action pulls the wheel into the cut rather than pushing it away from the cut. Avoid cutting into any adjacent panels that will not be removed.

Removing Spot Welds

Vehicle panels are often joined together by ***spot welds***. A factory spot weld is made by clamping the panels together between two electrodes. An electric current passes from one electrode to the other, fusing the clamped metal between the electrodes together. Most welds on a vehicle are of this type. A factory spot weld looks like a dimple in the metal. See **Figure 10-6**. Spot welds are found around the edges of welded-on panels.

Locate all spot welds before attempting to remove a welded-on panel. Spot welds may be hidden under trim or sealer. One way of locating spot welds is shown in **Figure 10-7**. Drive a chisel or putty knife between the panels. The spot welds are located in the areas where the panels will not separate. The welds may appear as small circles that will not move.

There are several methods of removing spot welds. Regardless of the method used, the technician must decide if the underlying panel can be cut. In most cases, the underlying panel, which is the panel that the damaged panel is welded to, should be preserved as well as possible. In some repair situations, such as when replacing a quarter panel at the seam inside the door, the spot welds can be drilled out and the drilling can continue until a hole is cut in the underlying panel. If the technician welds this seam from inside the vehicle, the holes in the underlying panel can be used for plug welds. This procedure will save time, eliminating the need to make holes in the replacement panel.

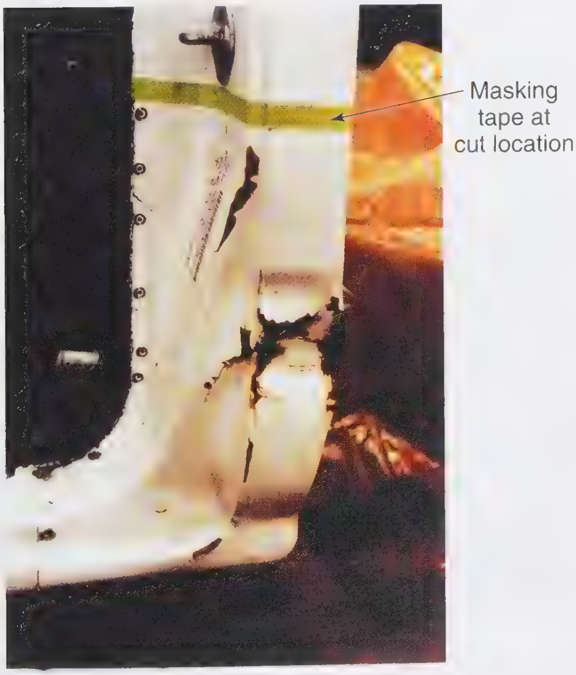


Figure 10-5. *Masking tape is used to mark the cut line. Notice that the spot welds have been removed along this panel.*

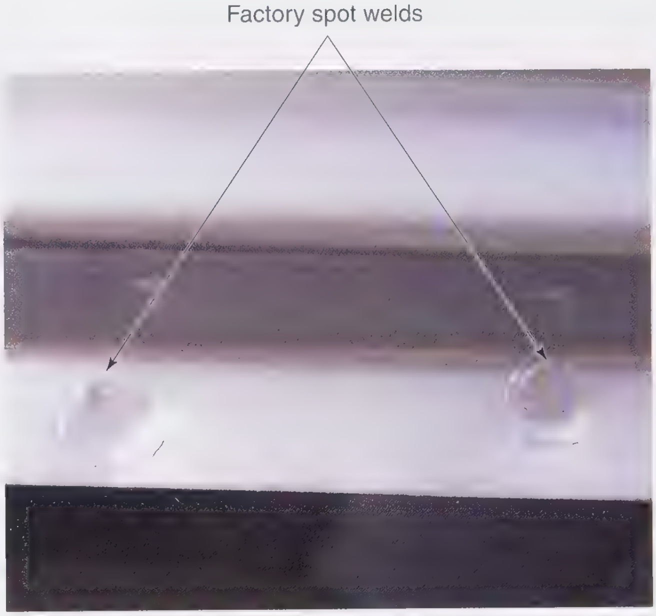


Figure 10-6. *Factory spot welds look like dimples in the metal.*

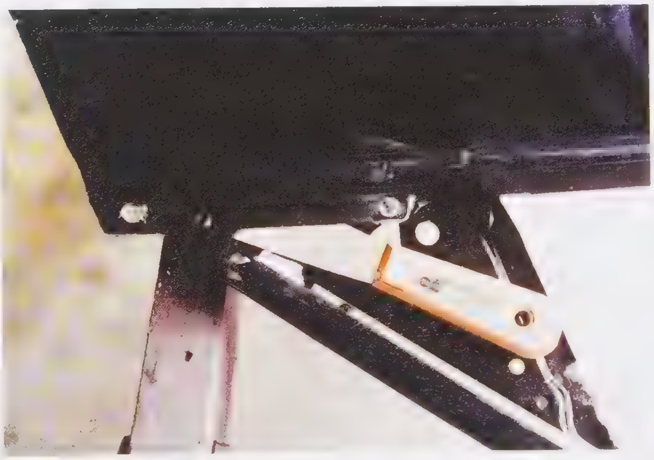


Figure 10-7. *Factory spot welds can be located by driving a tool between the panels. The panels will not separate where there is a weld.*

Cutting

A ***hole saw*** is commonly used to remove spot welds. To use a hole saw, first center punch the weld. Then drill a pilot hole with a 1/8" drill bit. The pilot hole will prevent the hole saw from walking off the weld. If the underlying panel is to be preserved, set the depth of the cut. If the upper panel is made of strong steel, cutting oil may be used on the hole saw. A dedicated spot weld cutter may also be used to remove spot welds. **Figure 10-8** shows spot weld cutting methods.

The hole saw will leave a nugget on the underlying panel once the upper panel is removed. The nugget can be ground off. A drill bit–type spot weld cutter does not leave a nugget. However, the depth of the cut cannot be controlled.

Grinding

Spot welds can be removed by grinding with a grinder or a cut-off wheel. The metal in the spot weld, as well as the surrounding metal, is removed from the upper panel. This leaves the underlying metal intact. See **Figure 10-9**. Grinding out a spot weld requires concentration.

CAUTION

Stop grinding immediately after the upper panel is ground through. Additional grinding will quickly damage the underlying panel.

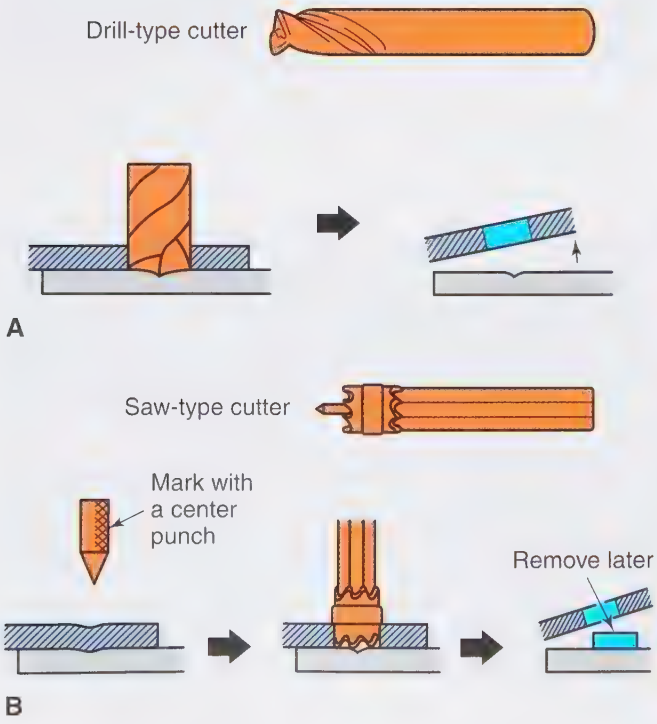


Figure 10-8. *Two spot weld cutting methods. A—Using a drill-type cutter. B—Using a saw-type cutter. (Toyota)*

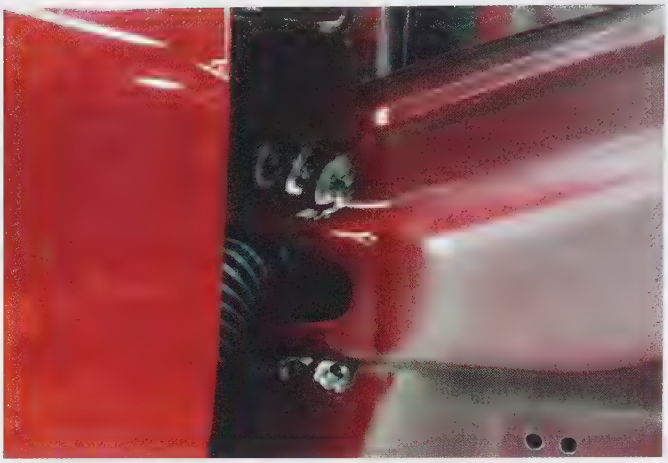


Figure 10-9. *These spot welds were ground out with a cutoff wheel. Using a hole saw would have required that the door be removed.*

Chiseling

Chiseling can be used to locate and remove spot welds. Actually, chiseling does not remove the weld; it just cuts off the upper panel. A ragged nugget will be left on the spot weld. Great care is required when using the air chisel. The chisel must be kept level. See **Figure 10-10**. If the chisel is held at an angle, it may cut into the underlying panel.

Once the spot welds are released, the panel should be loose. Wear gloves because sharp edges and ragged cut welds will be present. Most welded-on panels have sealer or adhesive holding them in place in addition to welds. Use a utility knife to cut the

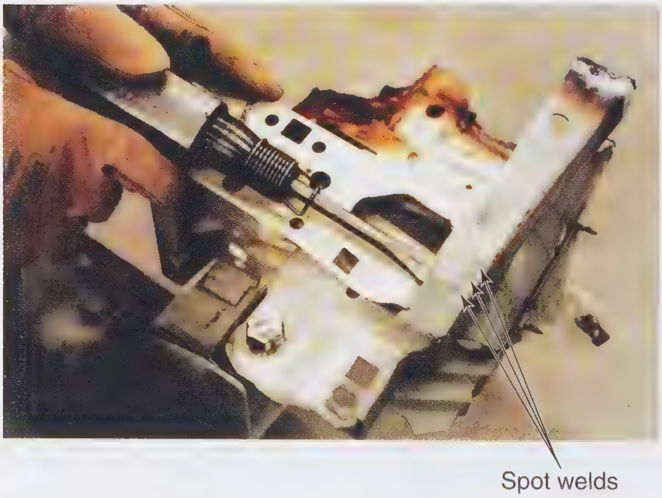


Figure 10-10. *Keep the air chisel level when cutting spot welds. Three spot welds are visible on this used radiator support assembly.*

sealer or adhesive. Do not try to pull the panel from the vehicle until all the welds are removed. Often, there are hidden welds that cannot be seen until the panel is partially removed. Drill these welds out as you find them. Once all spot welds and the adhesive or sealer have been removed, pull the panel off the vehicle. Use a putty knife to scrape off adhesive or sealer remaining on the mounting flanges. Clean up the ragged nuggets with a grinder.

Final Cutting

Test fit the replacement panel on the vehicle. Check that all panel gaps are the proper width and uniform. Inspect the mounting flanges to make sure the replacement panel will fit properly on the flanges. There should be no gaps between the flanges and the panel. Once everything lines up correctly, the panel or panels can be final cut.

For a butt joint, the area where the original panel and replacement panel overlap is marked with masking tape. A cutoff wheel the same thickness as one of the panels is installed in the cutoff tool. The cutoff tool is used to make the cut through both panels on the edge of the masking tape. The cut could also be made with an air saw or hacksaw. The gap between the panels will be the same thickness as the cutoff wheel or saw blade. The procedure for a sleeve joint is similar, but a wider joint is required. The sleeve is made from a 2"-long piece cut from the replacement part during the rough cut. If the sleeve is tapered and will not fit where it belongs, trim it to fit.

To make the final cut in a panel that will have a flange joint, install the replacement panel. Make sure that the original panel and the replacement panel overlap. Mark the final cut location on the replacement part with masking tape. Remove the replacement panel and make the cut on the edge of the masking tape. Reinstall the replacement panel and check all the gaps. Scribe a line on the original part at the edge of the replacement part. Remove the replacement panel. Measure the depth of the flange tool. See **Figure 10-11**. Determine one-half the depth of the flange tool. From the scribed line, measure back toward where the replacement panel will be installed one-half the depth of the flange tool. This will be the final cut line on the existing part. Mark the line with masking tape and cut. See **Figure 10-12**. For a lap joint, once the replacement panel is test fitted, make sure the panels overlap. At least 1/2" overlap is required. Cut the panels so the desired amount of overlap is maintained. A semi-butt joint is usually made with a flange joint. The procedures for determining where to make the final cut for a semi-butt joint are the same as those for a flange joint.

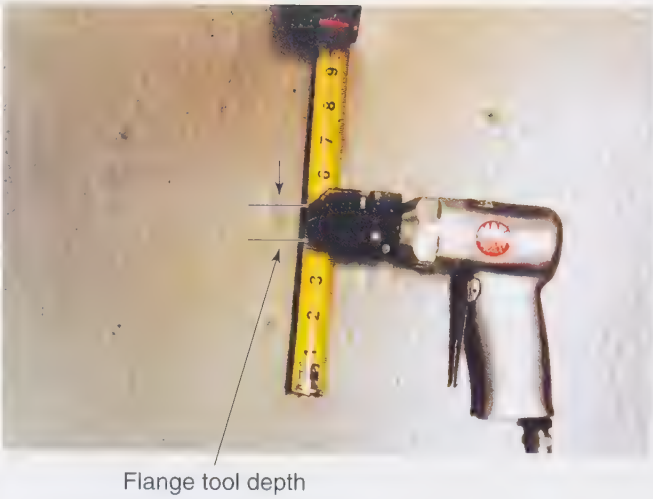


Figure 10-11. *By measuring the flange tool depth, an accurate cut can be made.*

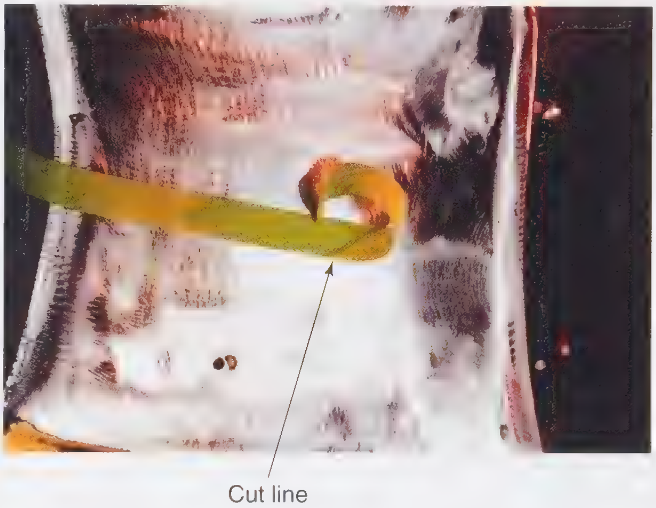


Figure 10-12. *In this example, the cut line needs to be 3/4" back from the scribed line. A piece of 3/4" masking tape is applied at the scribed line to locate the cut line.*

Preparing Panels

Proper preparation of a replacement panel and the existing panel will ensure that the repair is as durable as an undamaged vehicle. Preparation includes flanging the existing panel, if necessary, and removing the coating for welding or bonding.

A flange joint is commonly used in quarter panel splicing. Before making the flange joint, remove the paint from the area to be flanged. If the panel is flanged first, paint removal will be difficult. Remove the paint with 80-grit sandpaper. Do not use a grinder to remove the paint. Grinding may thin the metal, making welding difficult. Once the paint is removed from the area to be flanged, position the flange tool on the panel as shown in **Figure 10-13**. The tool should always be held against the edge of the panel. This will ensure a consistent flange depth. If the flange tool is not held against the edge of the panel, the flange will be ragged.

The flange tool works well on low-crown panels. However, on high-crown panels, this tool tends to flatten out the crown. A narrow-jaw flange tool can be used on high-crown areas to prevent flattening. Rounded corners, rather than square corners, will allow flanging to go around a bend. See **Figure 10-14**.

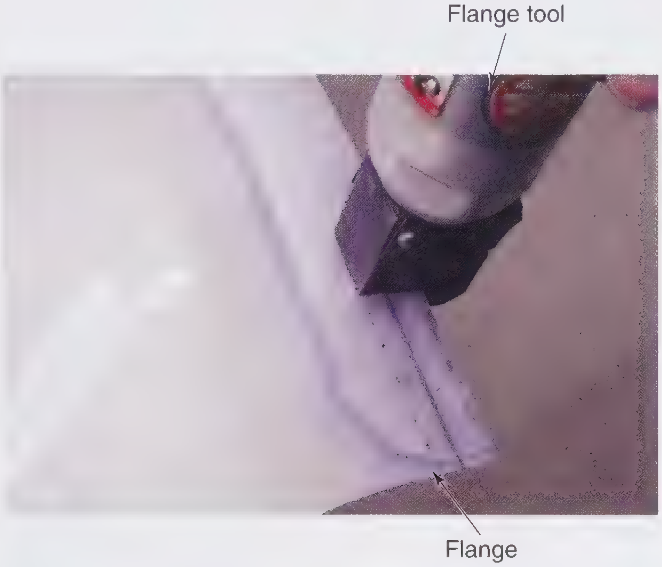


Figure 10-13. *The flange tool makes a step in a panel. Keep the flange tool tight against the panel to maintain a consistent step width.*

There are some areas where a flange tool head will not fit. In those areas, a semi-butt joint is used. See **Figure 10-15**. Instead of flanging these inaccessible areas, the original panel is bent down as shown in Figure 10-15A. To bend the panel down, insert a tool, such as a spoon, to support the edge of the bend and use a hammer to tap the panel down. See Figure 10-15B.

Areas to be welded or bonded should be sanded to bare metal. Use a dual-action sander with 80-grit sandpaper to remove primer and paint. Do not remove more primer than necessary. If welding, try not to remove any galvanized coating. The prep procedures for difficult types of welds and joints are listed below:

- Plug weld/lap joint or sleeve joint—Remove paint and primer from the upper side of the underlying panel along the mating surface (area where the panels overlap). Also remove the paint/primer from the underlying surface of the upper panel along the mating surface.
- Stitch weld/flange, sleeve, semi-butt, or lap joint—Remove the paint/primer from the flange area prior to flanging. Remove the paint/primer from both sides of the upper panel in the mating area.
- Stitch weld/butt joint—Remove the paint from the upper and lower surfaces on both panels, one inch from the joint.

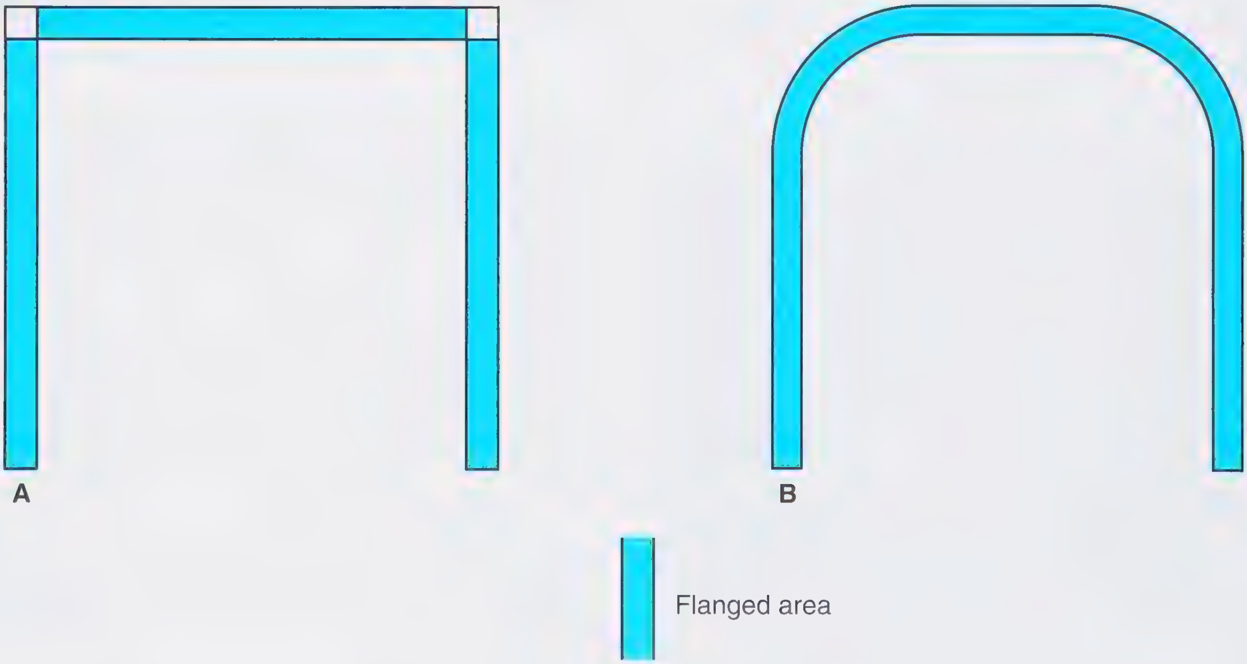


Figure 10-14. *A—The flange tool will not work in a square corner. B—Rounded corners allow the flange tool to make a continuous step.*

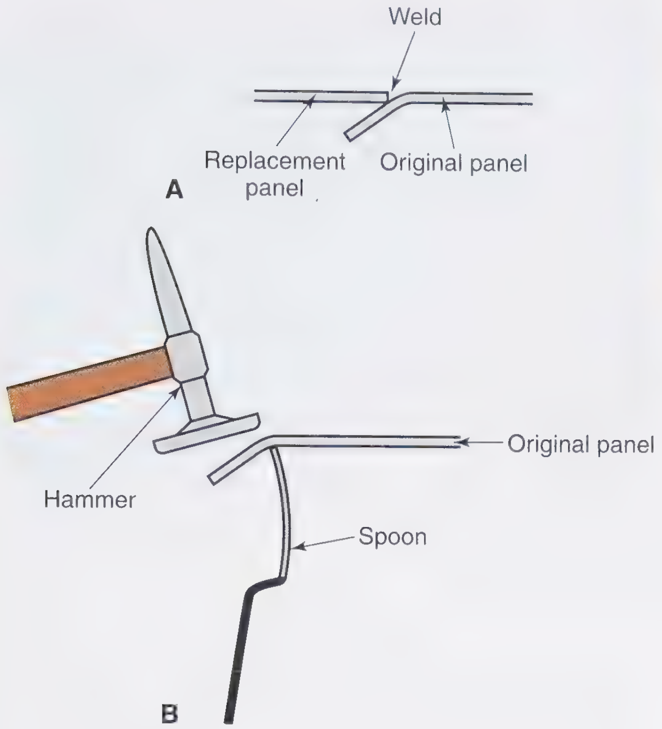


Figure 10-15. *A—In a semi-butt joint, the original panel is bent downward and the replacement panel is positioned near the bend line. B—The position of the spoon determines where the original panel will bend when making a semi-butt joint.*

Punch or drill 5/16" diameter plug weld holes as required. The bare metal should be sprayed with ***weld-through primer***. Weld-through primer contains zinc to inhibit rust. This product will protect surfaces that must be sanded to bare metal for welding but are not accessible after welding. See **Figure 10-16**. Weld-through primer is not required on bonded panels. The adhesive will protect the bare metal from rust. Remember, do not remove more primer than required. Adhesive covering the bare metal will protect it.

When using weld-through primer, follow the manufacturer's instructions. Usually two light coats are required. The panels can be fitted after the primer dries. Before welding, scratch the weld-through primer. Scratching will remove some of the primer and allow the MIG welder to strike an arc. Any visible weld-through primer will be removed and replaced with a different type of primer during refinishing operations. The refinish primer does a better job of protecting the bare metal.

Fit Up

Weld-Thru Coating

Figure 10-16. *Weld-through primer application is part of a high-quality repair.*

Replacement panel fit up requires that the panel be installed on the vehicle and clamped or screwed in place. The replacement panel can be held in place with clamps as long as they do not interfere when checking for fit. Clamping is faster than using screws. The clamps shown in **Figure 10-17** will be in the way when the door is shut to check panel alignment. Smaller clamps, **Figure 10-18**, eliminate this problem. One problem encountered when making a butt weld is that one or both panels will raise or lower from the heat of welding. Butt-weld clamps, **Figure 10-19**, secure the panels and help maintain the proper gap and height during welding.

Sheet metal screws can also be used to attach replacement panels. The sheet metal screws require that holes be drilled in the panel. The panel should be set in place and aligned as well as possible. A 1/8" drill

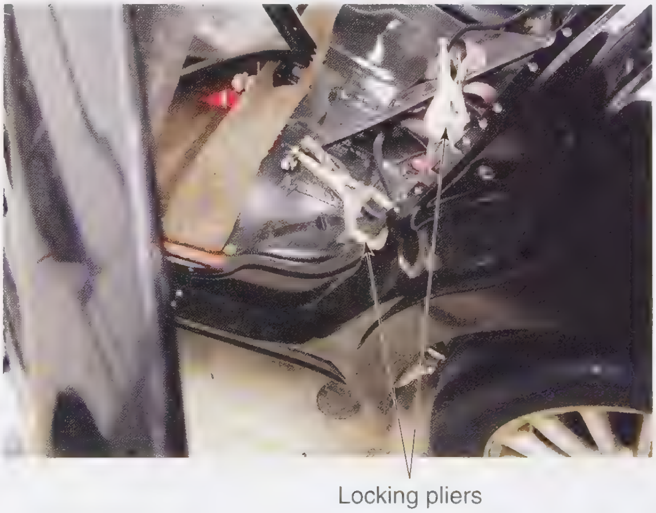


Figure 10-17. *Locking pliers are used to hold this replacement quarter panel in place. Notice the plug weld holes in the replacement panel.*

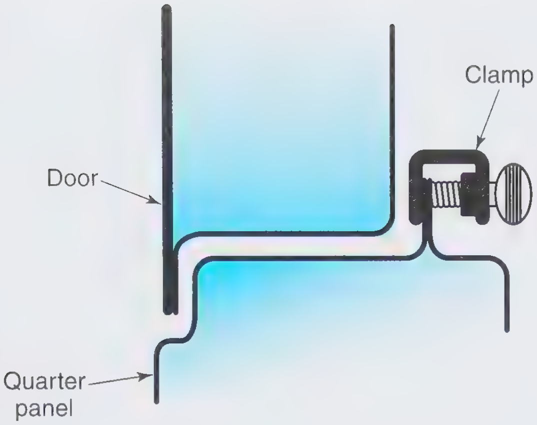


Figure 10-18. *Small clamps can hold the replacement panel and allow the door to be shut to check door and quarter panel alignment. (Steck Manufacturing)*

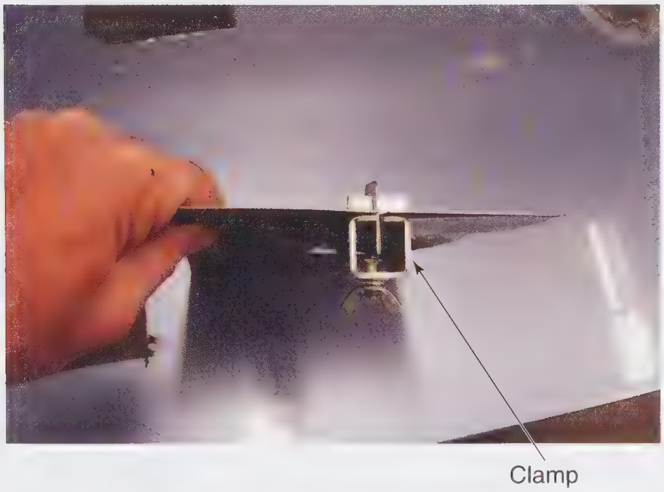


Figure 10-19. *The butt-weld clamp holds the panels at the proper distance and prevents the panels from changing height during welding.*

bit can be used to make holes in the replacement and underlying panels. After drilling the holes, insert a sheet metal screw to secure the panel. See **Figure 10-20**. Self-tapping screws can also be used. Screws can be placed along a flange joint.

Once the replacement panel is clamped or screwed in place, check the alignment of every adjacent panel or attached part. Look at panel gaps and install parts to make sure they fit properly. If a problem is found, remove the clamps or screws and reposition the replacement panel.

NOTE

Once the panel is welded or bonded in place, no adjustments can be made. Therefore, it is important to make sure the alignment is correct before proceeding.

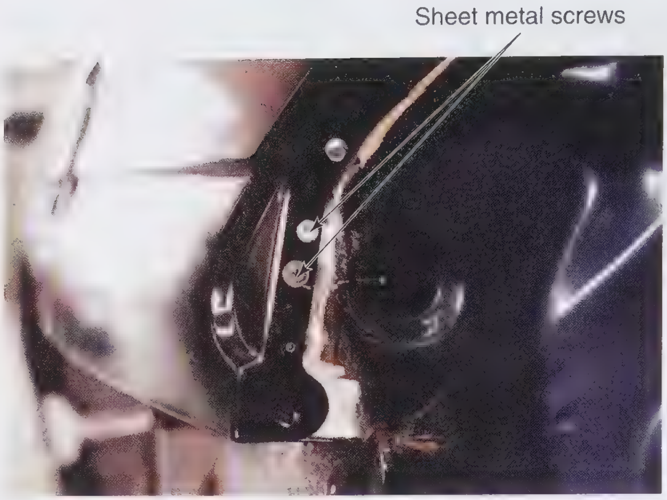


Figure 10-20. *Sheet metal screws hold a replacement panel for welding.*

Joining

Joining involves permanently attaching the replacement part to the vehicle. MIG welding is the most common joining method used in collision repair. MIG welding was covered in Chapter 5 of this textbook. ***Bonding*** involves the use of adhesives to join replacement parts to the vehicle. Bonding is used primarily on door skins, although quarter panels, roofs, and bed sides may be bonded if allowed by the vehicle manufacturer. ***Weld bonding*** is a combination of squeeze-type resistance spot welding and the use of adhesives.

Welding

The strength of the weld determines the quality of the repair. A weak weld may fail. For example, a replacement quarter panel was MIG welded on an SUV, but the weld did not have sufficient penetration. The spare tire rack was mounted on the quarter panel. Because the replacement quarter panel was not welded properly, the weight of the spare tire, aided by the movement of the rack while the vehicle was being driven, caused the welds to break. The customer brought the SUV back to the shop because the paint cracked in the area where the welds broke. As this example illustrates, the welds are the backbone of any repair.

If the replacement panel will be MIG welded in place, make a practice weld on the damaged part removed from the vehicle or on a scrap piece the same thickness as the replacement part. See **Figure 10-21**. The practice weld will help you determine whether the MIG welder settings are correct. Make adjustments to the setting as required. If MIG plug welds will be used to replace factory spot welds, use the same number of MIG welds as factory welds in the same location.

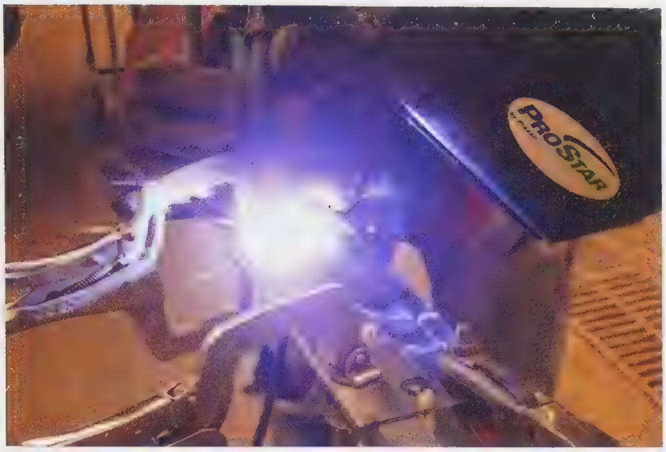


Figure 10-21. *This technician is verifying the MIG welder setting by making a test weld prior to welding a replacement panel.*

Proper welding requires that panels be tightly aligned. If one panel is higher than it should be, the upper panel may burn through when welded. Once the welding is completed, the screws are removed and the holes are welded shut.

Patch panels, fabricated panels made to fill a small area, can be welded in place with an electric resistance spot welder. This welder creates minimal distortion of the panel, although only lap joints are possible.

Bonding

Structural adhesive can be used to bond nonstructural panels. Check with the vehicle's manufacturer to see if bonding is allowed. One advantage to bonding is that corrosion protection is not burned off, as it is when welding. Additionally, the cured adhesive serves as a seam sealer.

Remove paint, primer, and galvanized coatings from the bond area. Place the adhesive cartridge in the adhesive gun and install a mixing tube. Squeeze the trigger to start the movement of the adhesive. As the adhesive flows through the tube, it will mix together. Discard the first two inches of adhesive.

Apply the adhesive to one of the panels to be bonded. The width of the adhesive bead will be specified by the adhesive manufacturer. Position the other panel on top of the adhesive. If the panel must be moved after the adhesive has met both panels, slide the panels into proper position. Lifting the panels may cause harmful gaps to form in the adhesive. For proper adhesion, the panels must be clamped tightly together. Sheet metal screws, weights, or locking pliers can also be used to keep the panels together. If some adhesive squeezes out from between the panels, wipe it off before it cures. Keep the panels clamped together until the adhesive has cured.

Bonding can be used on lap joints. Allow about a 1" overlap in the joint. The replacement panel is placed on the top. If the edge of the upper panel is beveled at an angle of twenty degrees, body filler can be applied after the cure to hide the joint. See **Figure 10-22A**. Another way to hide a panel splice is to use a sleeve. A bonded sleeve joint is similar to a welded sleeve joint. Cut the sleeve from the unused portion of the replacement part. It should be two inches wide. Prep the sleeve and install it with adhesive to the back side of the damaged panel. Once this has cured, fit and align the replacement panel. Next drill holes about one inch apart in the replacement panel, the sleeve, and any other point that will be held in place with screws. A tight fit between the replacement panel and the sleeve is critical for an invisible repair. Remove the replacement panel. Apply adhesive and install. Recheck the alignment and insert the screws, **Figure 10-22B**.

Remove the screws after the adhesive has cured. The screw holes can be filled with adhesive or aluminum body filler. Grind a featheredge in the hole with a cutoff tool. The featheredge will provide a larger surface area for the adhesive or filler to bond to. Also the featheredge will hide the edge of the hole when the panel is painted. The gap between the two panels is ground to a featheredge and filled also.

Weld Bonding

As the name implies, weld bonding is a combination of adhesive application and squeeze-type resistance spot welding. At least one vehicle manufacturer recommends

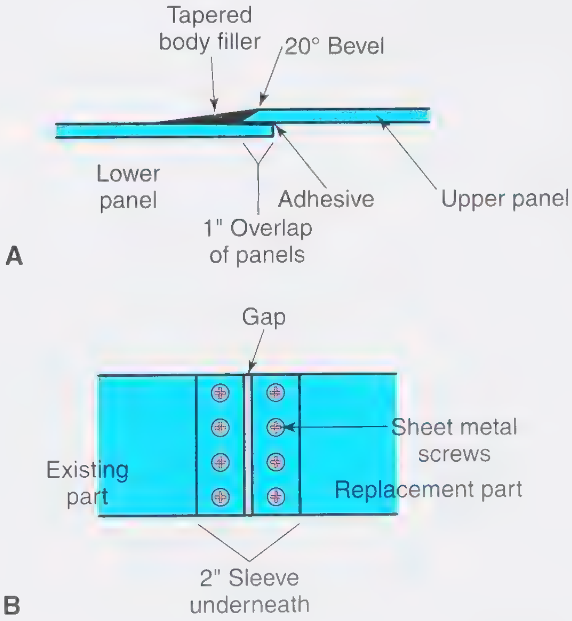


Figure 10-22. *A—The upper panel must be beveled to hide the overlap with body filler. B —Sheet metal screws hold the 2" sleeve in place while the adhesive cures.*

this technique for quarter panel, rear body panel, and roof replacement. The procedure for weld bonding is almost the same as that for bonding:

1. Prep the replacement panel and the vehicle for bonding by removing the paint, primer, and galvanized coatings from the mating surfaces.
2. Test fit the panels.
3. Apply the specified amount of adhesive to the mating surfaces.
4. Install the replacement panel. Clamp the panels together.
5. Use a squeeze-type resistance spot (STRS) welder to make the welds. If the spacing of the welds is not specified by the manufacturer, place one weld every 8". **Figure 10-23** shows a weld bonding procedure.

Finishing

Finishing is the last step in panel replacement. Finishing includes dressing the welds, filling weld gaps, and applying rust proofing. ***Dressing welds*** involves grinding welds and removing scale. MIG welding will leave a mound of weld on the joint. Because this mound does not strengthen the weld, it can be removed. Removal of the mound by grinding makes a plug weld look like a factory spot-weld. A MIG welded joint may also need to be ground down so the joint can be leveled with body filler. A STRS welder leaves a very neat weld, which requires little grinding, if any.

A grinder or a cutoff tool can be used to grind off the mound to remove excess weld material. A cutoff tool fitted with a grinding wheel is better to use on the MIG welds than a grinder equipped with a 24-grit disk. MIG welds are hard, and a grinding wheel will last much longer than a 24-grit disk. When dressing a MIG weld, always grind on the weld, not the surrounding metal. See **Figure 10-24**.

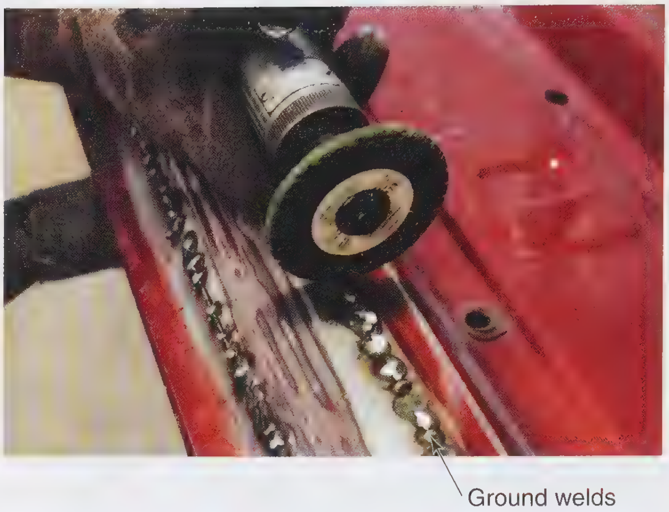


Figure 10-24. *Keep the disk on the weld and not the surrounding metal.*

CAUTION

The weld is hard and thick, but the surrounding metal is thin. If you grind on the surrounding metal with the same force as you grind on the weld, you will grind right through the metal.

Not all welds need to be ground down. Welds that will not be seen after the vehicle is assembled, called non-appearance welds, can be left as they are after the scale is removed. Weld scale is formed as paint and other impurities are burned by the heat generated in the welding process. Removing the scale allows the weld and surrounding bare metal to be coated with refinish primer. Scale can be removed with a wire wheel or wire brush. Check the fit of panels. A non-appearance weld

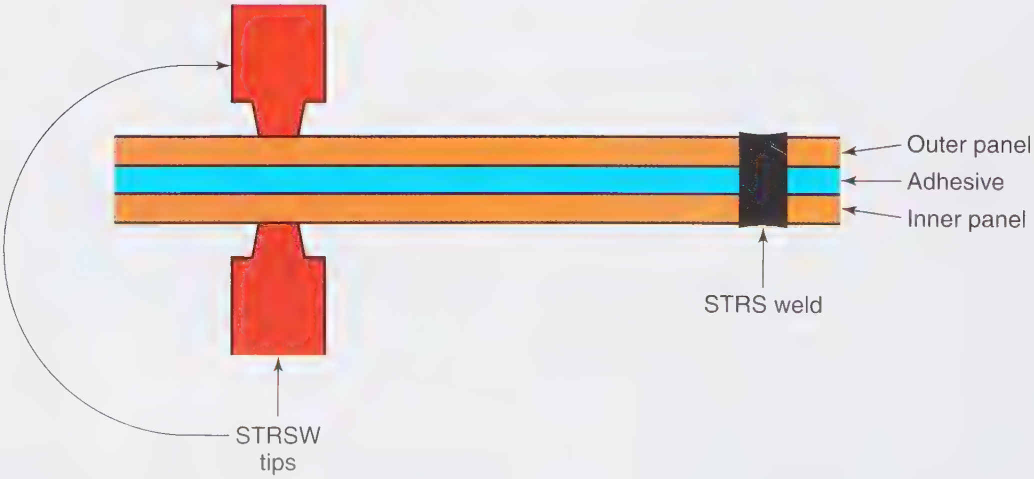


Figure 10-23. *The STRSW welds through the adhesive.*

may need to be ground down if the weld bead is so big that it prevents alignment of panels.

After dressing the welds, the weld gaps must be filled. **Figure 10-25** shows a flange joint that has been welded. Note that the weld does not fill the gap. Therefore, the gap should be filled with body filler. Some shops apply epoxy primer to bare metal and then apply body filler over the cured epoxy primer.

For proper adhesion, make sure that the weld scale is removed from the fill area before applying the filler. Apply the filler and sand the repair smooth after the filler cures.

Welding will burn the paint protection off the back side of a panel. The weld area will rapidly rust if it is not protected. Spray the weld areas with epoxy primer. If the weld area is inaccessible, such as in a dog leg, direct a stream of compressed air into the weld area. In the dog leg example, this can be done from inside the trunk. The air pressure may remove blistered paint. A special refinish tool called a wand is used to apply primer to enclosed areas. The wand uses a flexible tube to deliver primer to an area that would not be accessible with a spray gun.

Replacing Specific Nonstructural Panels

The typical repairs involving welded and bonded nonstructural panel replacement are quarter panel, roof, rear body panel, bed side, van side, cab corner, and door skin replacement. The steps in each of these repairs are similar. However, in specific operations, the sequence and number of steps will vary. Nevertheless, they will all involve, in one way or another, the basic procedures covered earlier in this chapter.

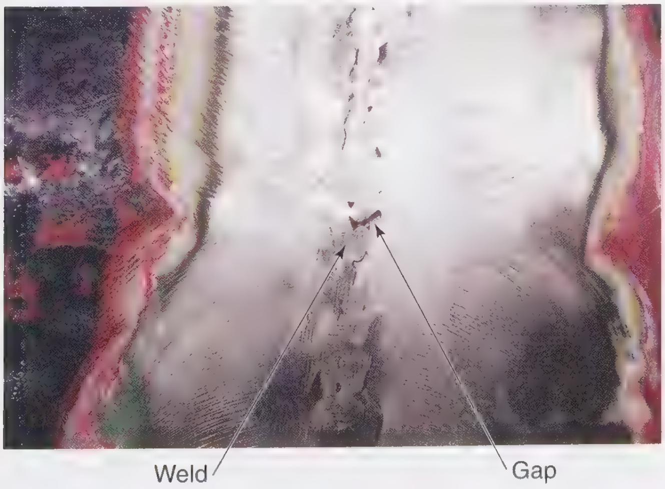


Figure 10-25. *A few gaps remain after welding and grinding this flange joint. The gaps can be filled with body filler.*

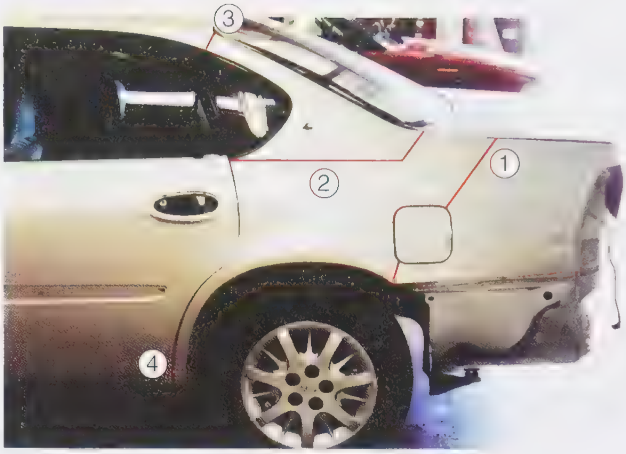


Figure 10-26. *Some finish work is avoided by making a splice through the gas door opening shown at 1. A splice at 2 eliminates the need to remove the rear and quarter glass. A splice at 3 requires the removal of the back glass and quarter glass. At 4, a splice eliminates the need for welding on the rocker panel.*

Quarter Panel Replacement

The most commonly replaced welded nonstructural panel is the quarter panel. Parts that may be attached to the outside of a quarter panel include the taillight, rear bumper, gas cap door, outer wheel house, ground effect panels, moldings, back glass, and quarter glass. On the inside of a quarter panel, there may be a trunk liner, trunk weather strip, door weather strip, door striker, and interior trim. When replacing a quarter panel, the vehicle should be set on its wheels and not jacked up on one corner. The replacement of a quarter panel is described below:

1. Read the estimate.
2. Analyze the damage—A replacement quarter panel will not fit properly if the unibody is damaged. If the rear frame rail, rocker panel, roof assembly, or wheel house has damage that is not straightened, the replacement quarter panel cannot be properly installed. Find all the damage prior to planning the repair.
3. Plan for the repair—Quarter panels are rarely installed as a full panel replacement. The splice location should take into consideration the amount of the panel that must be replaced, as well as the difficulty of finishing the splice joint. In this step, you must decide which splice location will repair the damage in the proper way in the least amount of time.

   OEM collision repair guides may list several acceptable splice locations. Follow these guidelines, if available. Typical splice locations are shown in **Figure 10-26**. This is a picture of a four-door vehicle. A splice at 1 is used when all damage is to the rear of the gas cap door. This will require a considerable amount of finishing. A splice at 2 eliminates the need to remove the back glass. Removal of the back glass is time-consuming, and there is always the possibility of breakage. Avoid removing the back glass if possible. A splice at 3 requires that the back glass be removed. A splice at 4 eliminates the need for a joint at the rocker panel.

Another example is shown in **Figure 10-27**. A splice at 1 eliminates the need to move the striker. The replacement panel is cut at the inner corner, and the damaged panel is cut at the outer corner. The panels are lapped and welded. The seam is hidden in the corner. Replacement at 2 is not a splice but a factory seam. The joint at 2 requires that the striker be repositioned.

4. Access—Begin on the inside of the vehicle. Protect or store any customer property that may be found in the trunk or the passenger compartment. Remove the trunk liner. Plastic rivets or clips are often used to hold the liner in place. Remove the rivets or clips, and pull out the trunk liner. See **Figure 10-28**. The trunk weather strip is usually held in place by friction. Pull it off.

   Inside the passenger's compartment, locate trim screws first. On some vehicles, it may be necessary to remove the rear seat to access the screws. Remove the trim screws and the door weather strip. Once the screws are out, the trim may be held in place by snaps or Velcro. Carefully pull on the trim. It can be easily broken, so do not force it. Once the inside is stripped, remove the exterior attachments, such as the taillight, rear bumper, moldings, and trim.

   One type of damage that may be present is outer wheel house damage. Because the quarter panel and outer wheel house are joined together, damage to the quarter panel will often extend into the wheel house. The outer wheel house is curved and straightening a curved panel can be difficult.

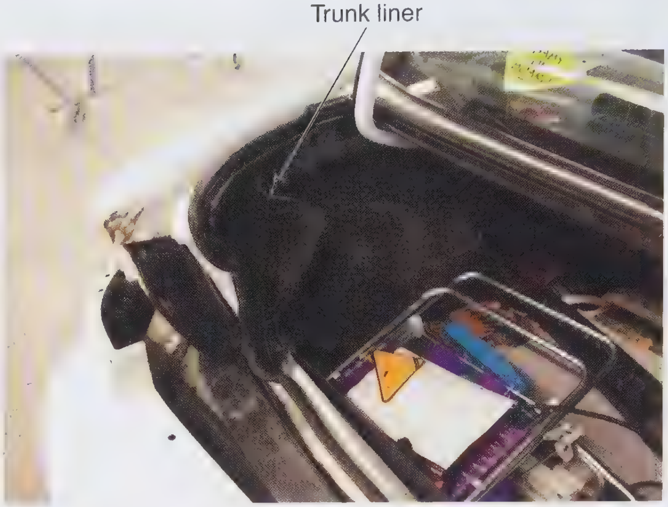


Figure 10-28. *Remove the trunk liner and weather strip for quarter panel replacement.*

Figure 10-29 shows a clamp and power post used to apply tension to a wheel house. Tension and hammering will work out the fold. A slide hammer may be used instead of a power post. Measure the distance from the inner wheel house to the outer wheel house on the undamaged side. This will help determine how far the damaged outer wheel house must be pulled during straightening. See **Figure 10-30**. Complete the straightening by hammering the flanged area flat.

If the wheel house cannot be straightened, the outer wheel house must be replaced before the quarter panel is replaced. Use a lap joint since the outer wheel house is not an appearance panel. Once the outer wheel house repairs are completed, continue with the rough cutting.

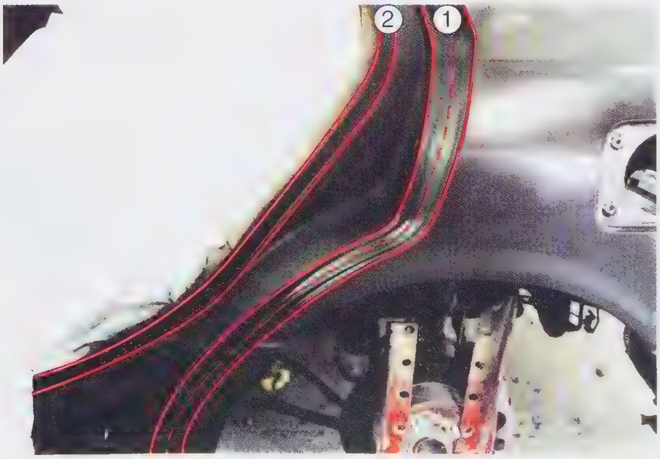


Figure 10-27. *A splice at 1 eliminates the need to move the striker. A splice at 2 is along a factory seam.*

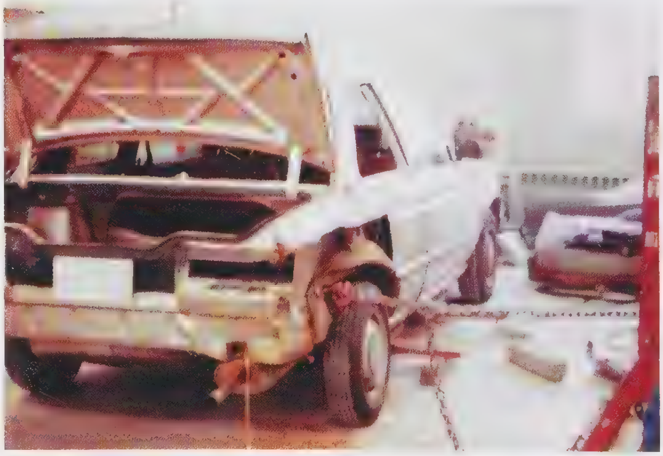


Figure 10-29. *This crumpled wheel house is straightened before the new quarter panel is installed.*

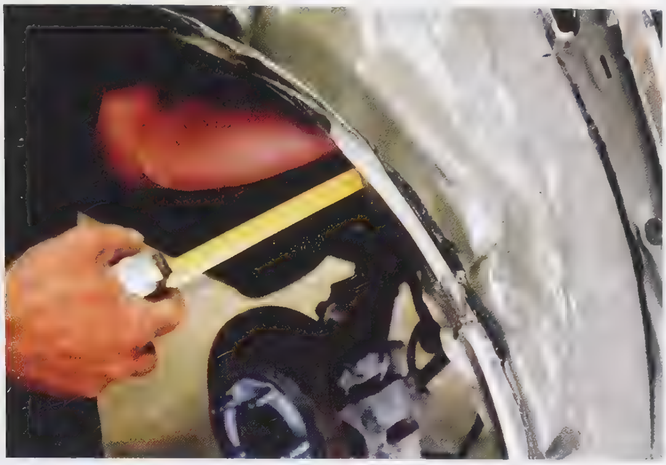


Figure 10-30. *Measuring the depth of the damaged wheel house and comparing the measurement to the undamaged side will indicate when the wheel house has been pulled out far enough.*

5. Rough cut—Locate and drill out spot welds. Be careful to cut only the damaged panel and not the underlying panel. The underlying panel will be needed to weld or bond onto the replacement panel. Rough cut the damaged panel about 2" away from where the final cut will be performed. Try not to cut through flanges or other parts of underlying panels. There may be glue holding the quarter panel in place, especially around the gas cap door, wheel house, and trunk areas. Cut this glue with a knife. Remove the damaged quarter panel. See **Figure 10-31**.
6. Final cut—With the splice location determined, the replacement panel is final cut. Mark a cut line with masking tape. The cut is made along the edge of the tape. A cut-off tool or an air saw can be used. The final-cut replacement panel is installed on the vehicle. If splices will be made, the replacement panel will fit over the rough cuts on the existing panel. See **Figure 10-32**. Check the alignment of all gaps. Shift the replacement part as needed to achieve perfect alignment. When the gaps are correct, scribe a cut line at the edge of the replacement part on the existing panel. Remove the replacement part and final cut the existing panel. The replacement quarter panel is set in place in **Figure 10-33**. The alignment is viewed from all angles. Shift the panel as needed to make the alignment correct.

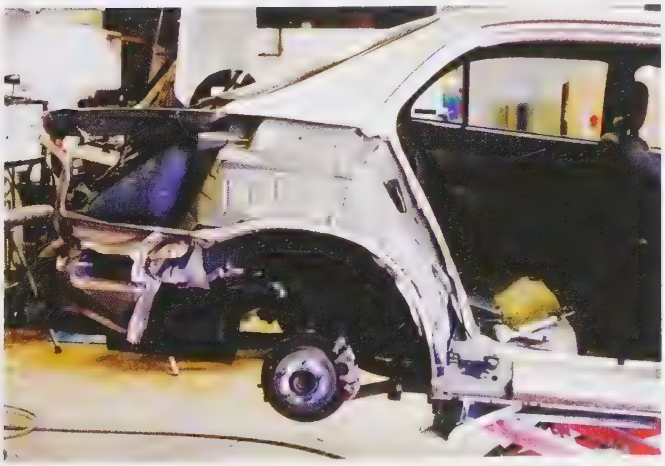


Figure 10-31. *This quarter panel has been rough cut. The splice will be made in the sail panel area.*

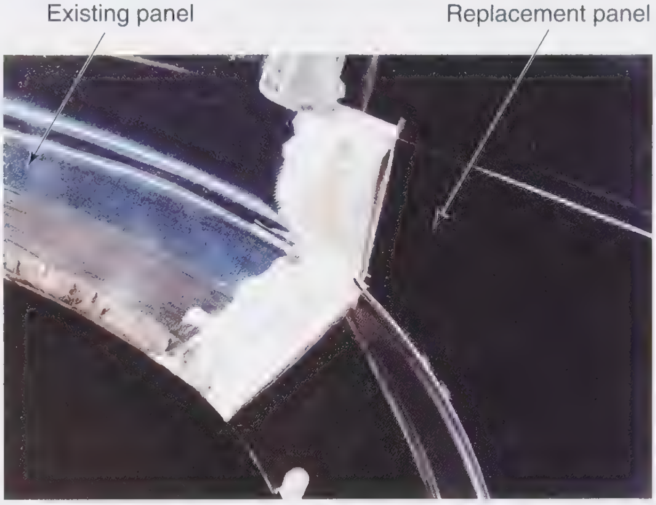


Figure 10-32. *The final cut replacement quarter panel is fit over the existing panel, and a line is scribed on the existing panel.*

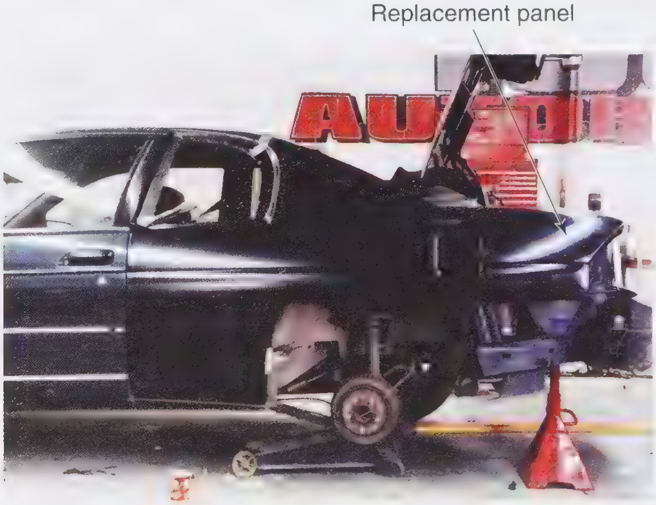


Figure 10-33. *The replacement quarter panel is installed for welding. Notice that the rear wheel needs to be installed so the vehicle is resting on four wheels during fit up and welding.*

7. Prepare the panels—Prepare the panels for welding by removing paint from the surfaces to be welded. Spray weld-through primer on the bare metal. If glued-on panel silencers are used on the inside of the panel, they should be installed at this time. If a flange joint is to be used, the panel is flanged at this time. If a sleeve is to be used, it should be made at this time. Cut the sleeve from the unused portion of the replacement panel. The sleeve is positioned at the joint and held in place with plug welds. Apply an adhesive or a sealer to the lip of the wheel house and any other place factory glue was found.
8. Fit up—Once both panels are prepped, the replacement panel can be installed. Use sheet metal screws to hold the replacement panel in place. On flange joints, there should be a 1/4" gap for the weld. On butt welds, the gap should be no wider than the thickness of the metal. On sleeve joints, the gap should be about 1/8". Check the panel gap between the replacement panel and the deck lid, as well as the gap between the replacement panel and the door. These gaps must be even. Install the taillight and the rear bumper. Make sure these components fit properly. If there is a splice in the sail panel, place the back glass in the rear window opening. Check the alignment of every adjacent panel and attached part. The alignment checks for quarter panels are shown in **Figure 10-34**. Once all panels are positioned correctly, welding can begin. Remove all attachments that might be damaged by welding.
9. Joining—When making a series of welds, start in the center and work outward, alternating from one side of the center to the other. Continue this process until the entire panel is welded. Once the panel is welded, remove the sheet metal screws and weld the holes shut. STRS welds can be made on the lap joints inside the window, trunk, and door or at the wheel opening.

   If the panel is to be bonded, drill holes for sheet metal screws and scribe alignment marks on the replacement panel and the damage panel. Then remove the replacement panel, apply adhesive, and reinstall the panel. Clamp the panel in place with sheet metal screws and locking pliers. If the panel is to be weld bonded, make welds after the panel is clamped in place.
10. Finishing—On a welded panel, dress the welds and remove scale or blistered paint. Apply plastic body filler to the splice joint as needed. Sand the cured filler. The heat of welding will burn paint off the backs of panels. To prevent corrosion, the primer must be replaced in these areas. On difficult-to-reach areas, spray epoxy primer from a wand onto the bare metal. Use a spray gun in accessible areas. If caulking is needed, it should be applied after priming.

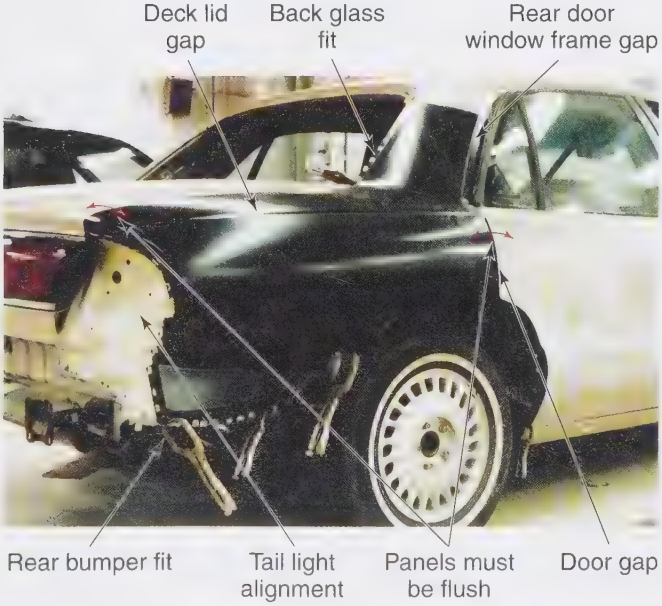


Figure 10-34. *Check all the areas shown for alignment before welding.*

Roof Replacement

A roof is a large, low-crown panel. The roof panel is strengthened by internal bows, as well as front and rear headers. The bows and headers are attached to the roof panel with a soft adhesive that acts as an antivibration material. The parts of a roof are shown in **Figure 10-35**.

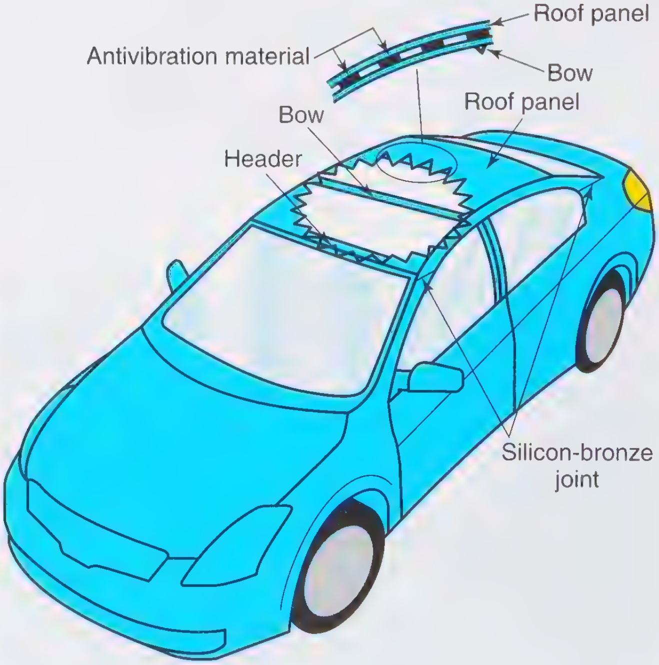


Figure 10-35. *The parts of a roof include the headers (front and rear), bows, antivibration material, and roof panel. The roof panel is joined to adjacent panels with a silicon-bronze welded joint.*

Roofs can be joined to the vehicle in three ways. In a channel-type roof, the roof and uniside are joined in a spot-welded lap joint. The lap joint is covered with a molding as shown in **Figure 10-36**. In a gutter joint, the roof is welded to a gutter and then the gutter is sealed. See **Figure 10-37**. In a wraparound joint, the roof joint is inside the doors. See **Figure 10-38**. Both the gutter-type and wraparound-type roofs have a seam at the windshield pillar and the sail panel. This seam is joined at the factory with a silicon-bronze joint. On a channel roof, the silicon-bronze joint is between the roof panel and the uniside.

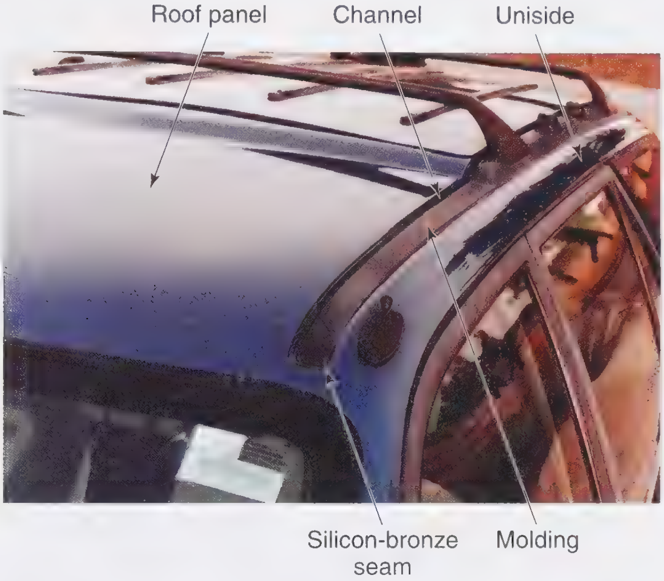


Figure 10-36. *The spot welds that join the channel roof to the uniside are under the molding.*

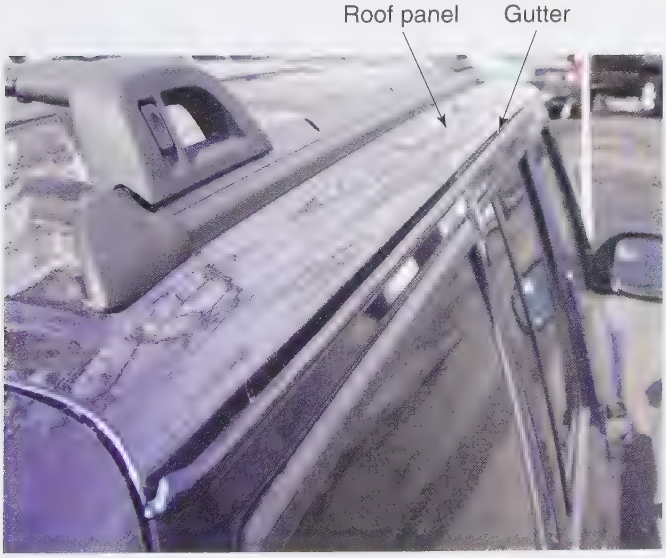


Figure 10-37. *The roof panel is spot welded to the gutter. The seam is filled with caulk.*

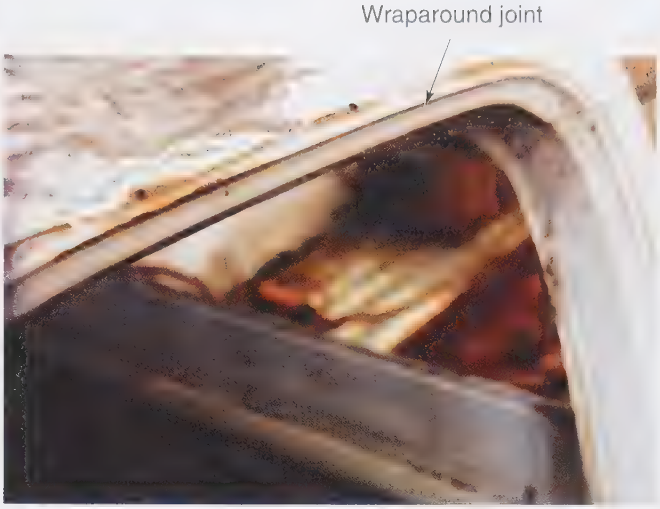


Figure 10-38. *The roof seam is inside the door on a wraparound roof.*

In roof replacement, the rough cut and final cut steps are combined. Roof panels are not spliced, so only one cut needs to be made. Replacement roofs can be welded or bonded. The replacement of a roof is described below:

1. Read the estimate.
2. Analyze the damage—Look at the damaged roof. Measure for misalignment by making X-checks from inside the vehicle. Any misalignment of the pillars or header should be straightened before removing the roof. Locate the silicon-bronze joints in the windshield pillars and sail panels by sanding off the paint with a dual-action sander and 80-grit sandpaper. The joints look like a narrow band of copper.
3. Plan the repair—Decide where the joints will be made. Roof panels cannot be spliced in the conventional manner. The silicon-bronze joint is always used as an installation point.
4. Access—Remove the front glass and back glass. Also remove the quarter glass, headliner, and dome light. The headliner may be held in place with Velcro. Cover the vehicle's interior to protect it from dirt, or remove the seats and roll back the carpet.
5. Rough cut/final cut—Locate the spot welds. **Figure 10-39** shows a typical location of spot welds on a roof. Drill out the spot welds. Look carefully at the replacement roof panel. If the roof panel is flanged, the flange slides under the pillar and sail panel. If the roof panel is not flanged, the roof sits on top of flanges in the pillar or sail panel. For panels that are not flanged, use a cut-off tool to carefully grind on the damaged roof panel at the silicon-bronze joint. See **Figure 10-40**. The grinding will remove the roof panel from the flange. Do not grind through the flange. To remove flanged panels, carefully cut the

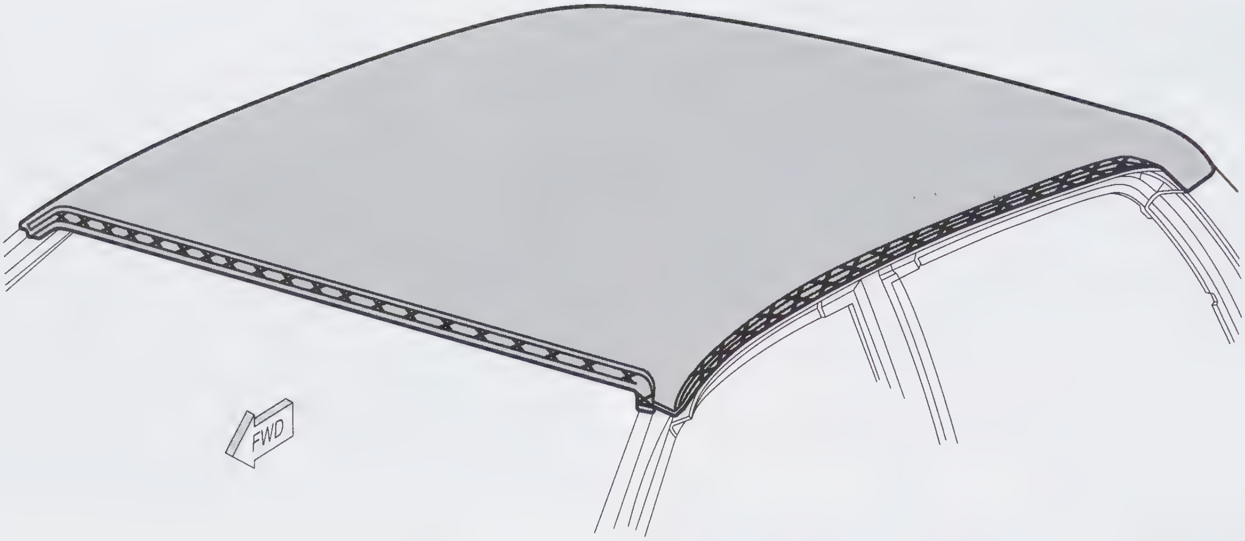


Figure 10-39. *This diagram shows typical spot weld locations on a roof.*

panel at the silicon-bronze joint. In either case, be careful not to damage the windshield pillar or sail panel. Cut the antivibration material with a hacksaw blade. Cut the glue or antivibration material from the bows.

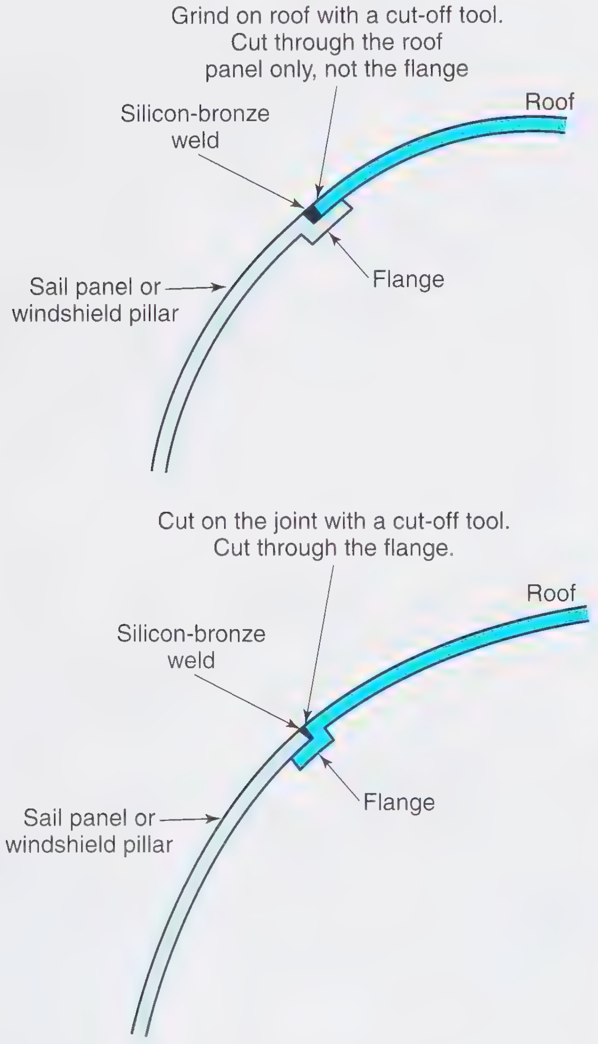

Grind on roof with a cut-off tool. Cut through the roof panel only, not the flange
Roof
Silicon-bronze weld
Flange
Sail panel or windshield pillar
A
Cut on the joint with a cut-off tool. Cut through the flange.
Roof
Silicon-bronze weld
Flange
Sail panel or windshield pillar
B

Figure 10-40. *A—If the roof is not flanged, cut the roof. B—If the roof is flanged, the cut should be made at the silicon-bronze joint.*

WORKING SMART

The "quick method" of roof replacement does not require the removal of the front or rear glass. Instead, only the quarter glass, front and back glass moldings, headliner, and dome light must be removed. In this procedure, the damaged panel is rough cut so 2"-wide sections of the original roof remain in place at the front and rear of the roof panel. The replacement roof panel flange is cut so that it will fit in between the remaining roof panel and the glass. See Figure 10-41. The replacement roof is glued to remaining roof panel and welded at the silicon-bronze joints. Weights or screws are used to hold the replacement panel in place at the front and rear window openings until the adhesive cures.

On a gutter-type roof, remove the sealer from the gutter. Then use a cut-off tool to remove the spot welds in the gutter. The roof will have a lap joint either over or under the windshield pillar and sail panel. This means the roof panel will either slip under the windshield pillar or sail panel, or it will be mounted on top of the windshield pillar and sail panel.

6. Prepare the panels—Prepare the replacement roof panel and related areas. If MIG welding the roof, punch holes on the flanges of the replacement roof for plug welds. Remove the paint in the weld areas and spray these areas with weld-through primer. Use

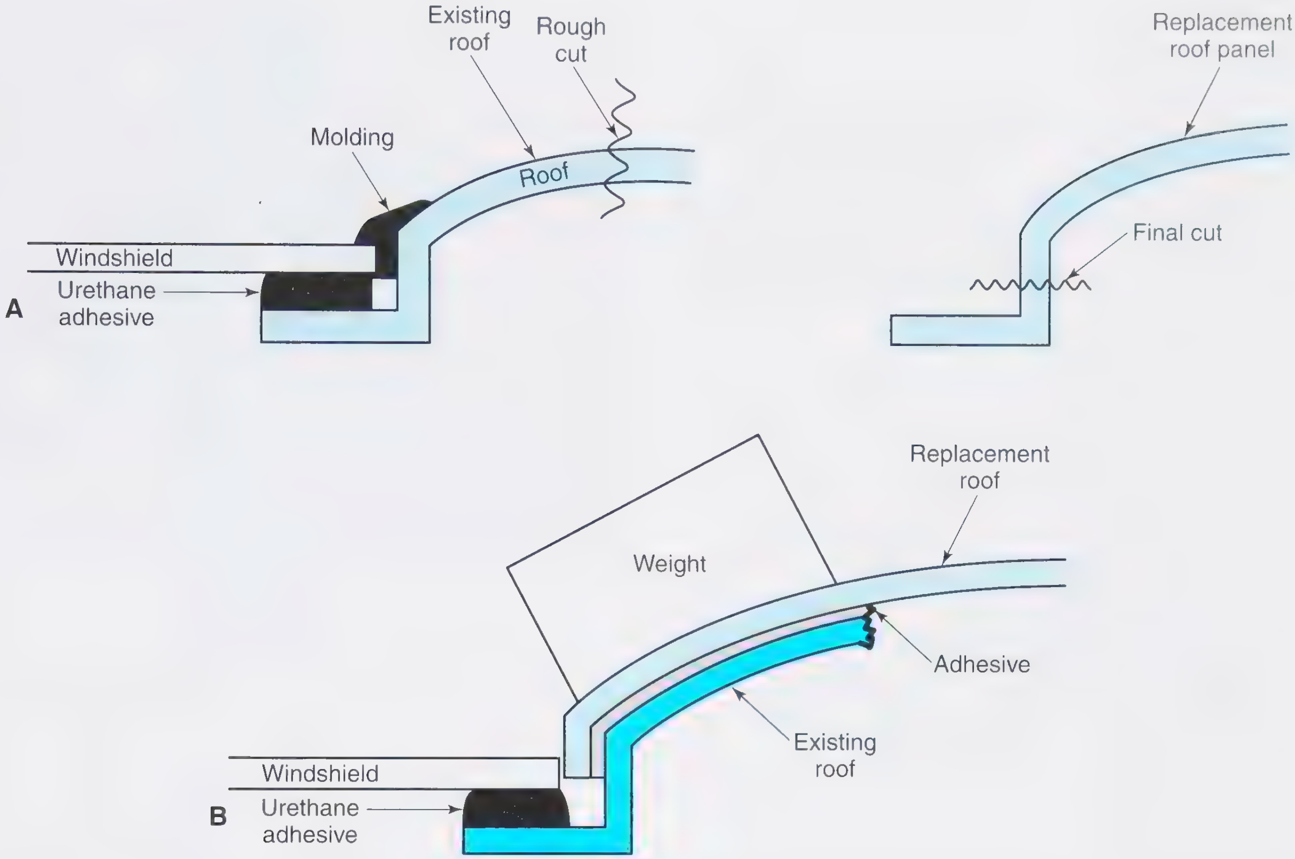

Existing roof
Rough cut
Replacement roof panel
Molding
Roof
Final cut
Windshield
Urethane adhesive
A
Replacement roof
Weight
Adhesive
Existing roof
Windshield
B
Urethane adhesive

Figure 10-41. *The "quick method" of roof replacement does not require front or rear glass removal. A—The damaged panel is rough cut so 2"-wide sections of the original roof remain in place at the front and rear of the roof panel. B—The replacement roof panel flange is cut so that it will fit in between the remaining roof panel and the glass. C—The replacement roof is glued to remaining roof panel and welded at the silicon-bronze joints.*

a cut-off wheel to remove silicon bronze from the joint area at the windshield pillar and the sail panel. A MIG weld will not stick to the silicon bronze. If the roof will be bonded, remove the paint and primer from bonding surfaces. Repair the bows as needed. Apply antivibration material or adhesive to the bows before installing the replacement roof.

7. Fit up—Once the replacement panel has been prepared, install it on the vehicle and check it for proper alignment. Roof panel alignment checks are shown in **Figure 10-42**. Test fit the glass and doors. When the alignment is correct, mark and remove the roof panel.
8. Joining—Align the roof and clamp it in place. If the roof is to be welded, clamp it in place and make the welds. The welds at the joints on the windshield pillar and sail panel must be MIG welds. The welds around the perimeter of the roof panel can be MIG plug welds or STRS welds.
9. Finishing—Grind and dress welds as needed. Apply filler to the seams and rustproof.

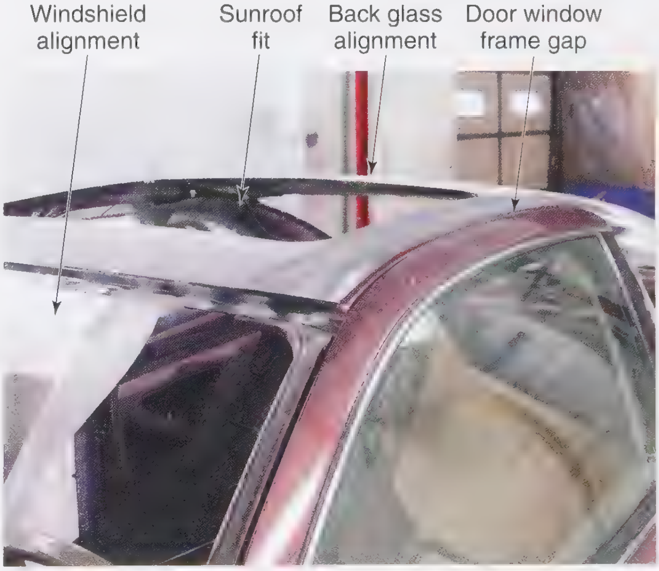

Windshield alignment
Sunroof fit
Back glass alignment
Door window frame gap

Figure 10-42. *These are the alignment checks for a roof. Check the fit of the windshield, back glass, and doors. If the vehicle has a sunroof, check it also.*

Rear Body Panel Replacement

The rear body panel is spot welded to the quarter panels, the trunk floor, and the end of the rear frame rails. A replacement rear body panel should be welded in place. **Figure 10-43** shows the location of spot welds on one particular vehicle. The replacement rear body panel should be installed as a complete panel. The typical procedure for replacing a rear body panel is as follows:

1. Read the estimate.
2. Analyze the damage—Look for damage to the quarter panels, trunk floor, and rear frame rails. The quarter panels should be aligned before removing a damaged rear body panel. However, pulling buckles out of the trunk floor or rear frame rails is easier after the rear body panel has been removed. With the panel removed, you have direct access to the floor or rail.
3. Plan the repair—Count the number of factory spot welds. Use the same number plug welds or STRS welds on the replacement panel. Decide which panels should be removed.
4. Access—Remove the taillights, rear bumper, and trunk lining.
5. Rough cut/final cut—Remove rear body panel by drilling out the spot welds.
6. Prepare the panels—Prepare the replacement panel and the mating flanges. Remove the paint in the area where the panels will be joined. Straighten or flatten the mating flanges with a hammer and dolly as needed. Punch or drill 5/16" holes for spot welds if the panel will be MIG welded. Apply weld-through primer to the panel edges.

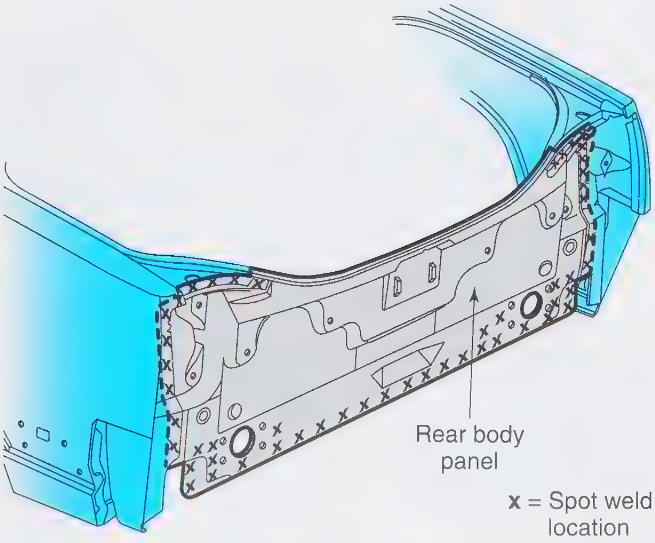


Figure 10-43. *This diagram shows spot weld locations on a typical rear body panel.*

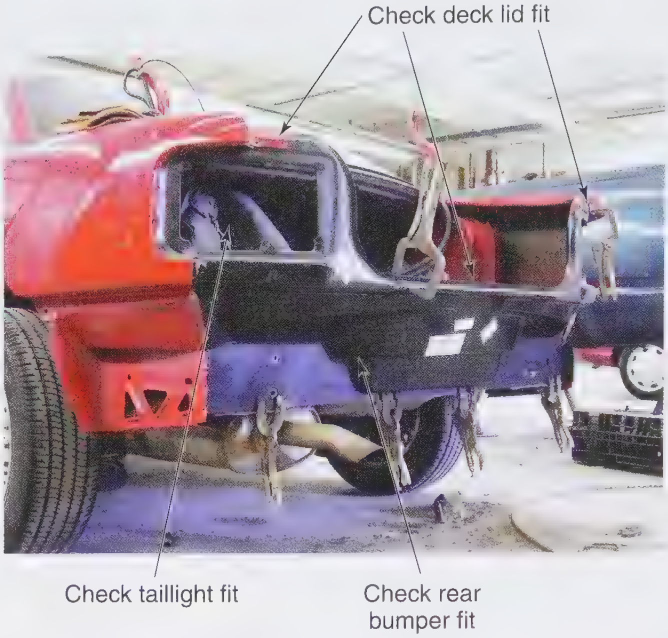


Figure 10-44. *Check the deck lid, taillights, and rear bumper for fit before welding a rear body panel.*

7. Fit up—Check alignment as shown in **Figure 10-44**. Make sure the rear bumper and taillights fit properly. Close the deck lid and check the gap. On the vehicle shown in the Figure 10-44, the gap between the deck lid and the rear bumper should also be checked.
8. Joining—Make the plug welds or the STRS welds.
9. Finishing—Dress the plug welds or STRS welds as needed.

Bed Side Replacement

The bed side of a pickup truck consists of inner and outer walls, as well as the wheel house and a portion of the bed floor. **Figure 10-45** shows the parts of a bed side. The bed side skin is the outer wall only. If the damage only involves the outer wall, just the skin can be replaced. If the damage extends into the bed, the entire bed side should be replaced.

The steps in bed side replacement are listed below:

1. Read the estimate.
2. Analyze the damage—Check the vehicle for frame damage. If frame damage is present, remove the bed. This will make it easier to repair the frame. Look over the entire bed for damage. The wheel house, floor, or front panel can all be damaged. If the bed side, wheel house, and floor are all damaged, it may be more cost effective to obtain a new or used bed assembly than to replace each part individually.

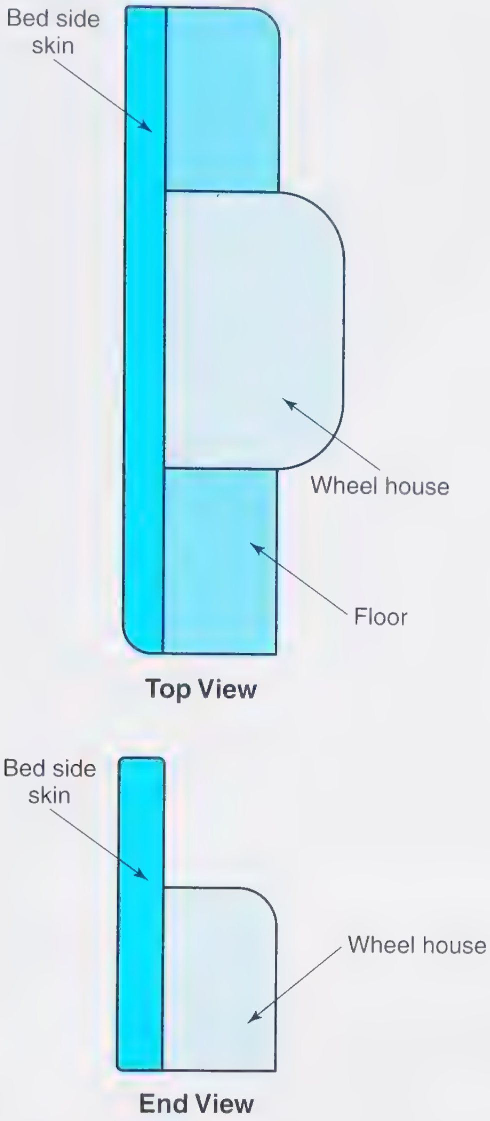


Figure 10-45. *The parts of a bed side are shown in this illustration.*

3. Plan the repair—The bed side should not be sectioned. It is easier to replace the entire panel than to finish a section joint in a bed side. Decide if the entire bed side or just the skin will be replaced. A replacement bed side skin can be bonded or welded. However, some bed side skins are very difficult to install, requiring a lot of shifting and stretching to make them fit properly. These skins should be welded rather than bonded. If adhesive were used on a difficult-to-install bed side skin, it would be very messy.
4. Access—Remove the tailgate and taillight. Remove the bolts holding the bed to the frame. Move the bed away from the cab far enough for access to the front of the bed. If enough assistants are available, lift the bed off the frame and place it on stands.
5. Rough cut/final cut—Locate and drill out spot welds. **Figure 10-46** shows spot weld locations on a bed side and a skin. Drill through the outer panel only. Straighten any damage to the wheel house (skin) or bed floor (bed side).
6. Prepare panels—Punch holes for plug welds in the replacement panels. Use the same number of plug welds as factory welds. On the original panel, grind down the excess metal where the spot welds were drilled out. Remove paint with 80-grit sandpaper on a dual-action sander. Spray weld-through primer on the weld areas.

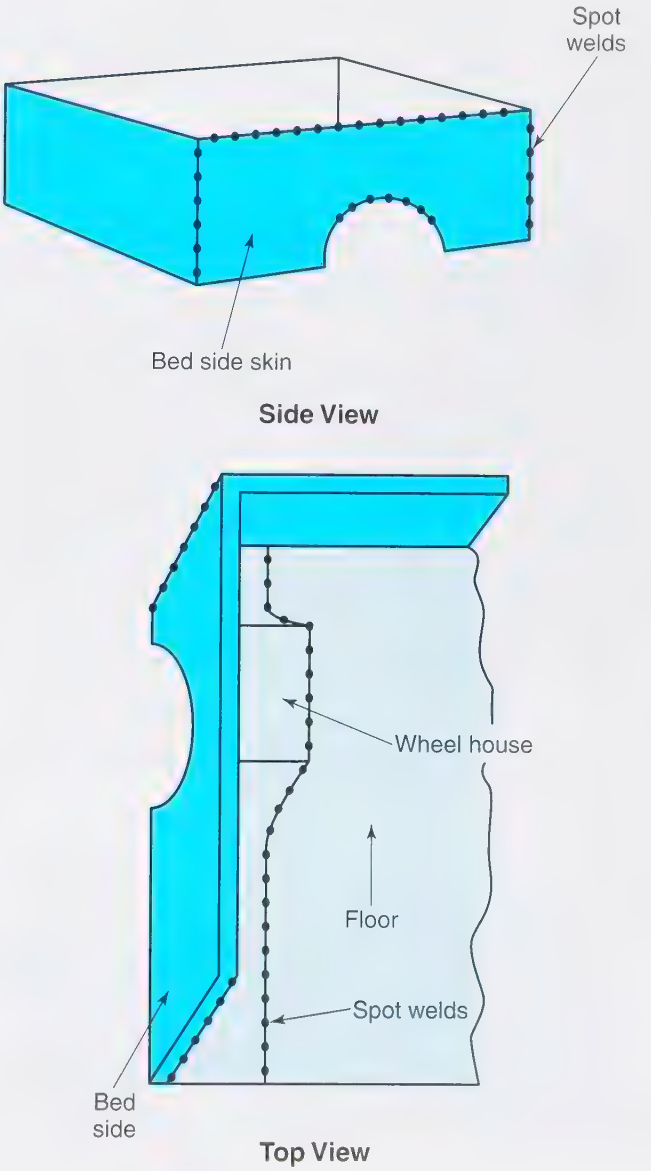


Figure 10-46. *The spot welds on a bed skin are found along the interior perimeter. The spot welds on a bed side are found on the front and back, as well as along the floor.*

7. Fit up—Install the replacement panel on the bed. A skin may be very difficult to install. Slip it in place using a putty knife as shown in **Figure 10-47**. Clamp the panel in place or install sheet metal screws to hold it in position. Reinstall the bed and check the alignment of the replacement panel. **Figure 10-48** shows the alignment hand checks that should be made. Check the operation of the tailgate.
8. Joining—MIG plug weld the holes or use a squeeze-type resistance spot welder. Start in the center of the panel and work toward the ends. Dress the welds with a cut-off tool.
9. Finishing—Most of the welds on a bed side will be non-appearance welds. Welds on a bed side skin will be appearance welds so prep and fill any uneven plug welds. Remove blistered paint from the back side of welded panels. Spray with epoxy primer. On a bed side, place sealer in the seam at the bed floor.

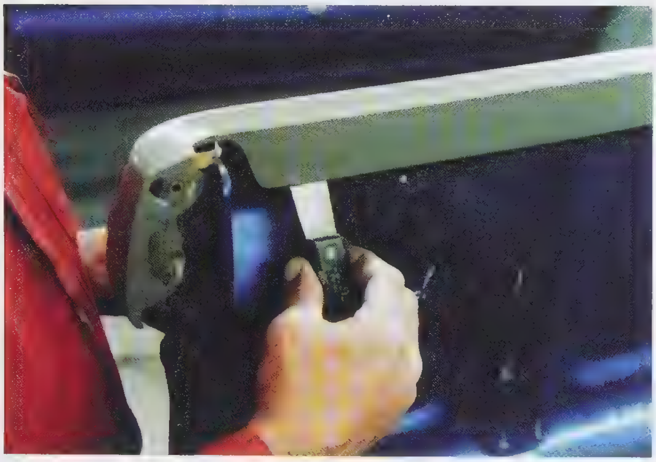


Figure 10-47. *A bed skin can be difficult to install. Using a putty knife to slip the bed skin in place helps.*

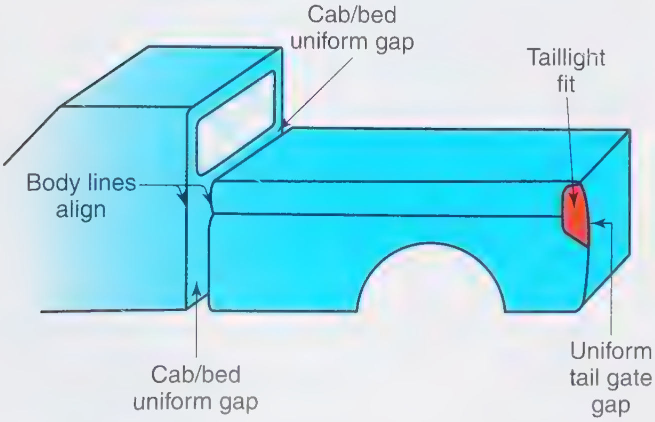


Figure 10-48. *These are the alignment checks that should be made before welding the replacement panel.*

Cab Corner Replacement

The cab corner on a pickup truck is similar to the quarter panel on a car. Both types of panels can be spliced and both butt against the back glass, roof, rocker panel, and door.

1. Read the estimate.
2. Analyze the damage—Check the panel and adjacent panels for damage.
3. Plan the repair—The parts of a cab corner are shown in **Figure 10-49**. A splice can be made near the roof. Use a portion of the replacement panel to make a sleeve. Some technicians use a body line to hide a splice joint in a cab corner. The damaged panel is cut 1" below the body line. The replacement panel is cut on the body line. The replacement panel is welded at the body line.
4. Access—Remove or move back the bed. Remove the back glass. Remove interior trim and the seat, if they are in the way.
5. Rough cut—Locate and drill out the spot welds. Cut the upper portion of the damaged cab corner about 4" below the roof. Remove the damaged panel.
6. Final cut the replacement panel—Cut the replacement panel about 2" down from the roof joints. Place the replacement panel on the damaged cab. Check

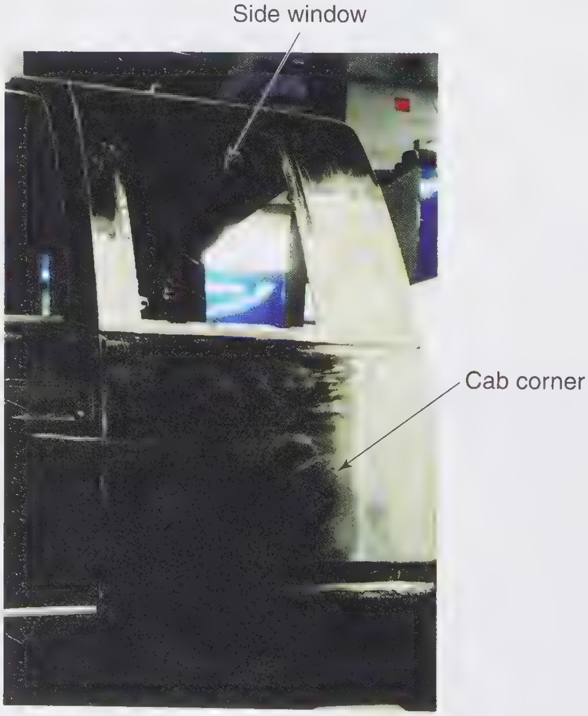


Figure 10-49. *This is a cab corner on an extended cab. An extended cab includes a rear window. The cab corner extends from inside the door to around the back of the cab. The back glass opening forms an edge on the panel.*

the alignment gaps. Scribe a cut line for the splice joint. The cut line is scribed along the edge of the final-cut replacement panel. Final cut the damaged panel at the scribed line.

7. Prepare the panels—If the replacement panel will be welded in place, punch plug-weld holes in the replacement panel. Grind down any remaining spot welds on the damaged panel. Remove paint from weld surfaces with 80-grit sandpaper on a dual-action sander. Spray weld-through primer in the weld areas. Cut the sleeve, remove the paint, and spray the sleeve with weld-through primer. Position the sleeve and use sheet metal screws to hold it in place. If the replacement panel will be bonded, remove paint from the mating surfaces.
8. Fit up—Position the replacement panel on the cab. Check the alignment as shown in **Figure 10-50**.
9. Joining—MIG plug weld the holes and stitch weld the splice. Dress the welds. If the replacement panel is to be bonded, remove the panel and apply the adhesive. Then, reinstall the cab corner, clamping it in place.
10. Finishing—Clean up the splice joint and apply body filler. Remove any blistered paint. Spray the repair area with epoxy primer and apply sealer.

Van Side Replacement

The procedure for replacing a van side is similar to that for replacing a quarter panel. The van side is spliced at the roof with a lap joint. A lap joint is used because the factory seam is too difficult to reach. If the lap joint is made so the replacement panel is just under the gutter, the seam will be invisible. A van side is a very large panel, but it is held in place with spot welds and antivibration material like the other panels. The steps for van side replacement are as follows:

1. Read estimate.
2. Analyze the damage—Inspect for damage to the inside supports and the floor.
3. Plan the repair—Decide where the van side will be cut and what parts need to be removed.
4. Access—Remove moldings from the van side. If there are windows in the van side, they should be removed. If a sliding door is present, it should be removed. Finally, remove the rear bumper.
5. Rough cut/final cut—Remove the damaged van side. Begin by drilling out the spot welds. Then cut the van side 1 1/2" below the roof gutter. Use a hack saw to cut the anti vibration material between the inside supports and the van side.
6. Prepare the panels—Remove the weld nuggets from the damaged vehicle. Remove the paint/primer and apply the weld-through primer. Punch plug weld holes in the replacement panel.
7. Fit up—Install the replacement van side. Check for alignment as shown in **Figure 10-51**.
8. Joining—MIG plug weld the replacement van side in place. Minimize heat distortion near the roof by allowing each weld to cool before making the next weld.
9. Finishing—Grind the welds and apply filler as needed.

Door Skin Replacement

The types of doors are shown in **Figure 10-52**. The door shown in Figure 10-52A does not have a frame around the window. In this design, the door skin is the panel below the glass. Figure 10-52B shows a door with a frame around the glass. However, the frame is not

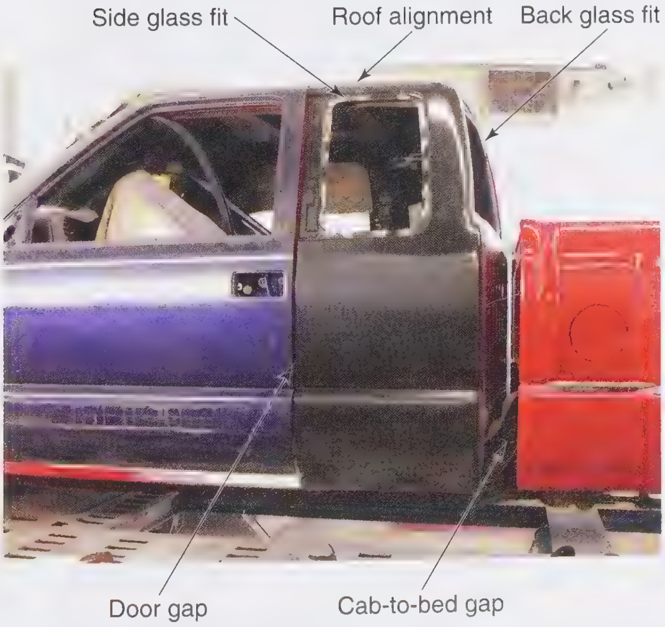


Figure 10-50. *These checks should be made to the cab corner before welding.*

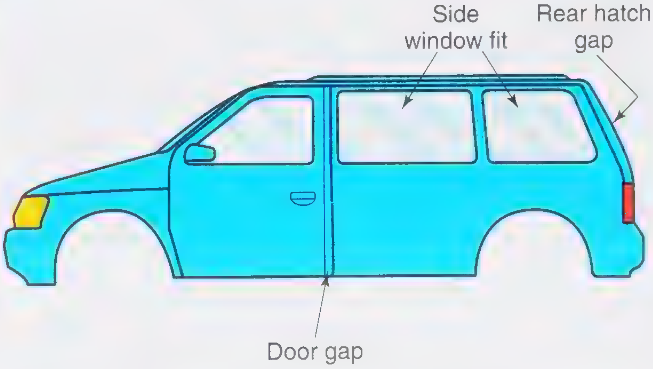


Figure 10-51. *Before welding the van side, check the rear hatch gap, door gap, and side window fit.*

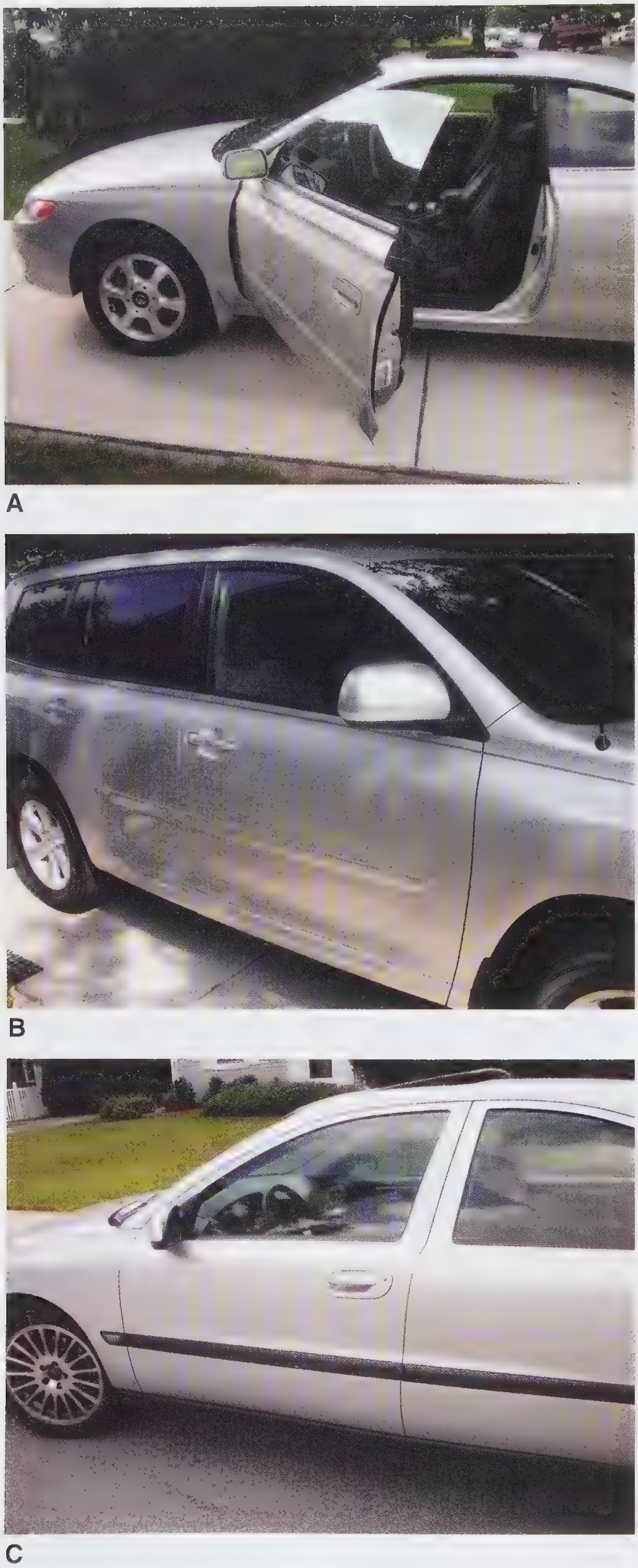


Figure 10-52. *Various types of doors. A—This door does not have a frame around the window. B—This door has a frame around the glass. C—On this door, the window frame is part of the door skin.*

part of the skin; the skin is the panel below the glass. Figure 10-52C shows a door in which the window frame is part of the skin. This type of skin can be spliced in the window frame. The parts of a door are shown in **Figure 10-53**. A door skin is shown in **Figure 10-54**. The door skin flanges are not folded over. After the new skin is installed on the door shell, the flange will be folded over.

The procedure for replacing a door skin is as follows:

1. Read estimate.
2. Inspect damage—Look over the damage. Find all damage on the door and the adjacent panels.

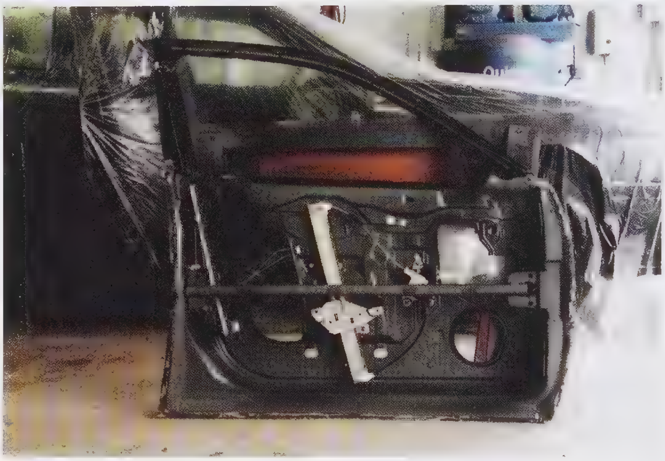


Figure 10-53. *The door skin has been removed from this door. Note the internal parts that are visible.*

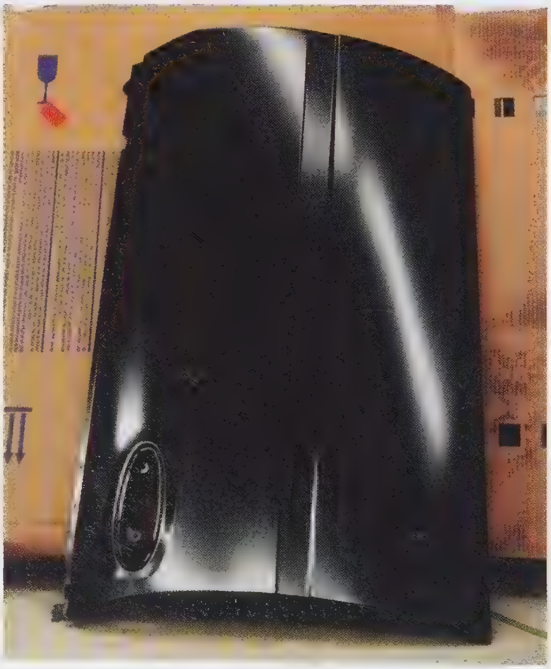


Figure 10-54. *This is a replacement door skin. The hem flange is folded at a 90° angle.*

The door may have been hit hard enough to damage both the door skin and the door shell. Removing the door skin allows access to door shell damage. The flange on the door shell can be straightened with a slide hammer. If the damage is extensive, involving more than the door skin and the door shell flange, a new or used door may be required. Determine if the hinges are welded on.

3. Plan—Decide if the window frame can be spliced. A splice in the window frame will allow the paint to be blended on the window frame. This will eliminate the need to blend the paint into the roof. If the entire skin is installed, the paint may need to be blended into the roof.
4. Access—Align the damaged door before removal. Adjust the window frame for a good seal. Compare the body lines on the door with the body lines on the fender and the adjacent door or the quarter panel. The body lines should be flush and at the same height. If an edge of the door is low compared to the adjacent panel, use a slide hammer with a hook to pull out the edge of the door. Aligning the damaged door before removal saves time when checking the door for fit after the door skin is installed.

   Next, remove the trim panel. If there is a main junction for the wires running into the door, disconnect it. If no junction can be found, disconnect the wires from the window regulator, lock, speakers, and mirror (as necessary). Then pull the wires from the door. Remove the window glass, run channels, and belt moldings. Disconnect the door handle and lock rods. Unbolt the door handle and remove it. Slide the clip out of the lock and remove the lock. (The handle and lock may be one unit). Position a floor jack at the rear of the door so the door will be supported when the hinges are released. If the hinges are bolted on, unbolt the hinges from the door. If the hinges are welded on, remove the spring with a door-spring compressor and then knock the pins out of the door hinges. Remove the door and place it on sawhorses.
5. Rough cut—Locate and drill out the spot welds. The welds will usually be along the upper edge of the door. There may also be inside tabs with spot welds. If the window frame will be spliced, rough cut the frame, allowing at least 1" of extra metal below the intended splice location. Remove the hem flange around the edges of the door skin by grinding as shown in **Figure 10-55**. Grind until the hem flange breaks open. Three layers of metal will be visible when the hem flange breaks open. Grind all the way around the door frame to remove the skin. Once the hem flange is ground down, cut the skin loose from the crash beam. The skin may also be glued to the upper portion of the door frame. Cut this glue with a razor knife. Use a putty knife to remove the skin as shown in **Figure 10-56**. Remove the remains of the hem flange. Leave the paint edge to serve as a guide for the new skin. Straighten the door flanges with a hammer and dolly. If a splice joint will be used in the window frame, rough cut the replacement skin. Cut the replacement skin about 1" longer than the joint location. Fit the replacement skin in place. Align the skin using body lines for reference. The replacement skin should fit into the folds exactly. See **Figure 10-57**.
6. Final cut—Cut both panels at the splice joint. The splice joint can be a butt joint if the width of the window frame is less than 2". If the width is greater than 2", use a sleeve. The sleeve must be cut to fit inside the window frame. The sleeve should be at least 2" long and as wide as the frame will allow. Remove the skin.

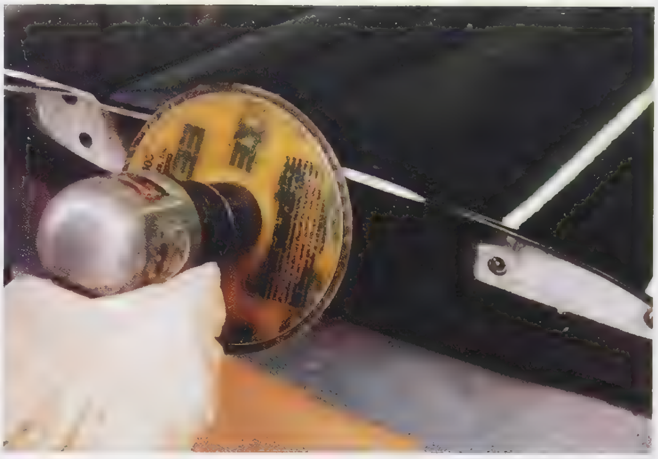


Figure 10-55. *Grinding away the hem flange will begin to separate the door skin from the door frame.*

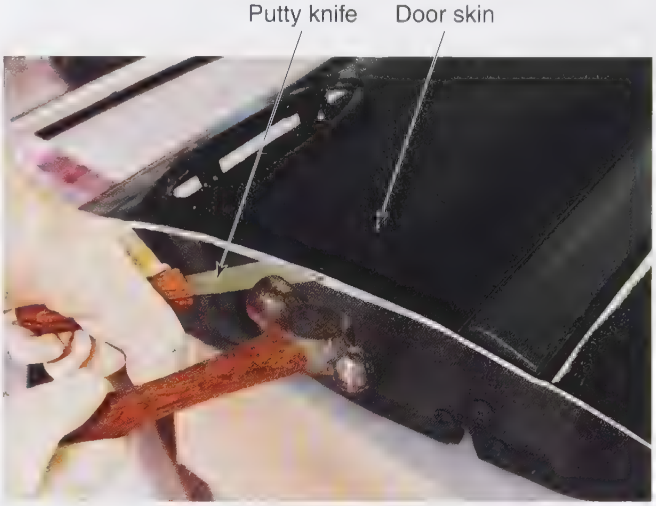


Figure 10-56. *A putty knife driven around the door skin will break the adhesive bond that holds the skin to the door frame.*

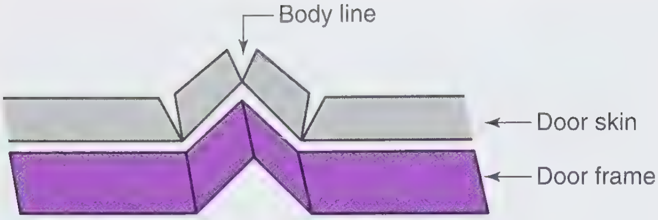


Figure 10-57. *Check the alignment of the skin at the body lines and at the hem flange edges. Once the alignment is correct, the splice joint can be cut.*

7. Prepare the skin and frame—Remove the factory primer from the door skin flange and the mating surfaces of the door skin and door frame with a plastic-coated abrasive wheel. See **Figure 10-58**. Read the directions on the adhesive. A special primer may be needed for bare metal. Punch holes for plug welds as needed. Remove the spot weld nuggets from the frame by grinding. Remove paint by sanding with 80-grit sandpaper on a dual-action sander. Spray on weld-through primer in the weld area. Check the adhesive instructions. The adhesive instructions may list a working time. The ***working time*** is the number of minutes between the application of the adhesive and the time the adhesive begins to cure. Apply a 1/4" bead of adhesive to the mating surface of the door frame. Also apply adhesive to the crash beam.
8. Fit up—Position the door skin by aligning the skin with the window frame and then dropping it in place. Once the adhesive makes contact with the skin, reposition the skin only by sliding. Lifting the skin from the door frame will break the adhesive bond. Position the skin by aligning the folds or body lines. Use wooden paint sticks and small vise grips or C-clamps to hold the skin in proper position. See **Figure 10-59**. The paint sticks prevent damage to the door skin. Position the door so the door skin is facing down. Be sure to use padding to prevent damage to the skin. Folding the hem flange can be a physically demanding task. Use a door skin hammer and a 9" hard plastic sanding block or a power door skinning tool. **Figure 10-60** shows how the edge of a sanding block is used to support the edge of the skin. The hammer is used to fold the flange. Start at one side of the door and bend the flange to a 45° angle. Once one side is bent to a 45° angle, complete the folding by bending the flange flat. To prevent damage to the outer skin, use many light hammer blows.

When the damaged door skin was removed

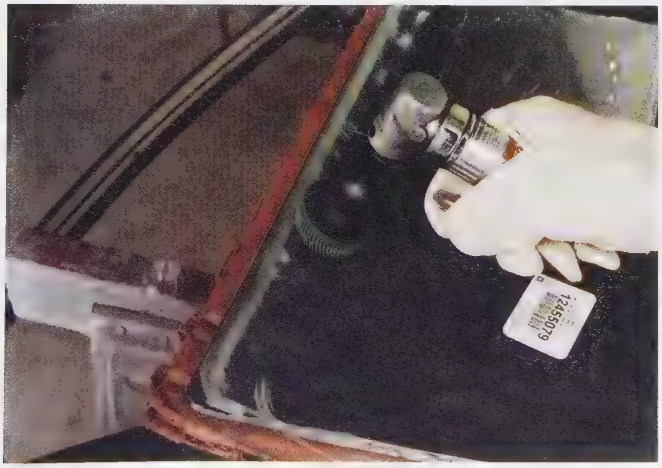


Figure 10-58. *Factory primer is removed from the area where adhesive will be applied.*

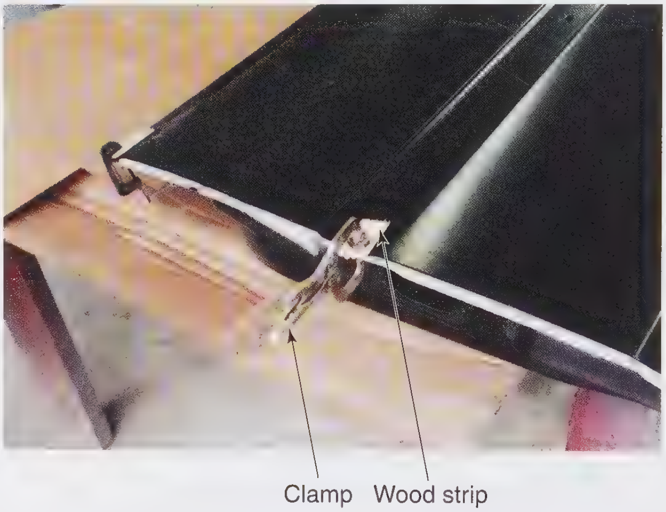


Figure 10-59. *Wooden sticks between the clamp and the panel help prevent damage.*

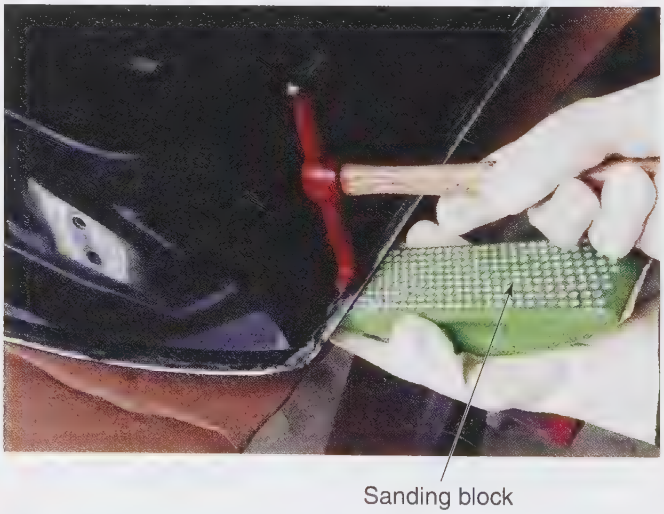


Figure 10-60. *A sanding block can be used instead of a dolly when folding over a hem flange.*

from the inside of the door, a paint edge was exposed. The paint edge shows where to install the new door skin for a good fit. The folded flange should line up with the paint edge. Once one side is done, fold the hem flange on the other side of the door. Then finish with the hem flange on the bottom of the door. Test fit the door prior to welding. By this time, the adhesive will be set up. Install the door on the vehicle. Check the alignment. **Figure 10-61** shows the alignment checks that should be made. Remove the door. Some shops leave the door mounted on the vehicle while the adhesive cures.

9. Weld/bond—MIG weld the plug holes and the splice joint.
10. Finish—Dress the welds. Feel the edge of the door skin for ripples or dents caused by folding the flange. If irregularities are found, use a body file along the edge. Follow with 80-grit sandpaper on a dual-action sander set on grinder mode.

Patch Panel Installation

Patch panels are fabricated to fill a rust hole. They are generally cut from a scrap piece of properly shaped sheet metal. Patch panels can be bonded or welded in place. The steps of reading the estimate, examining the damage, planning the repair, and accessing are followed in the same order as the previously explained repair methods. In examining the damage, probe the panel with an awl or a sharp punch to locate all rust-weakened metal. All rust-weakened metal must be identified and cut out. Rust thins metal. The thin metal tends to burn through when it is welded. Final cut the patch panel before rough cutting the rust hole. Position the patch panel to cover the rust hole and scribe a line

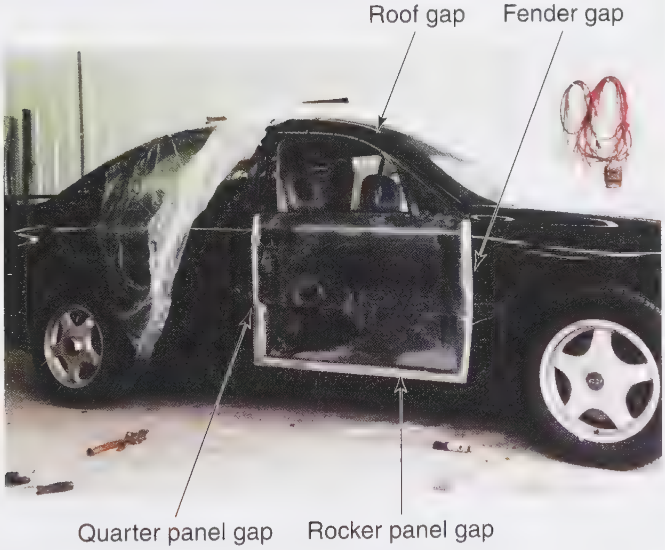


Figure 10-61. *The door panel edge has been worked to eliminate surface irregularities. Check the alignment at the bottom, the windshield pillar, the fender, and the quarter panel. Also check for flush. Make sure the panel surface has no dents or bulges.*

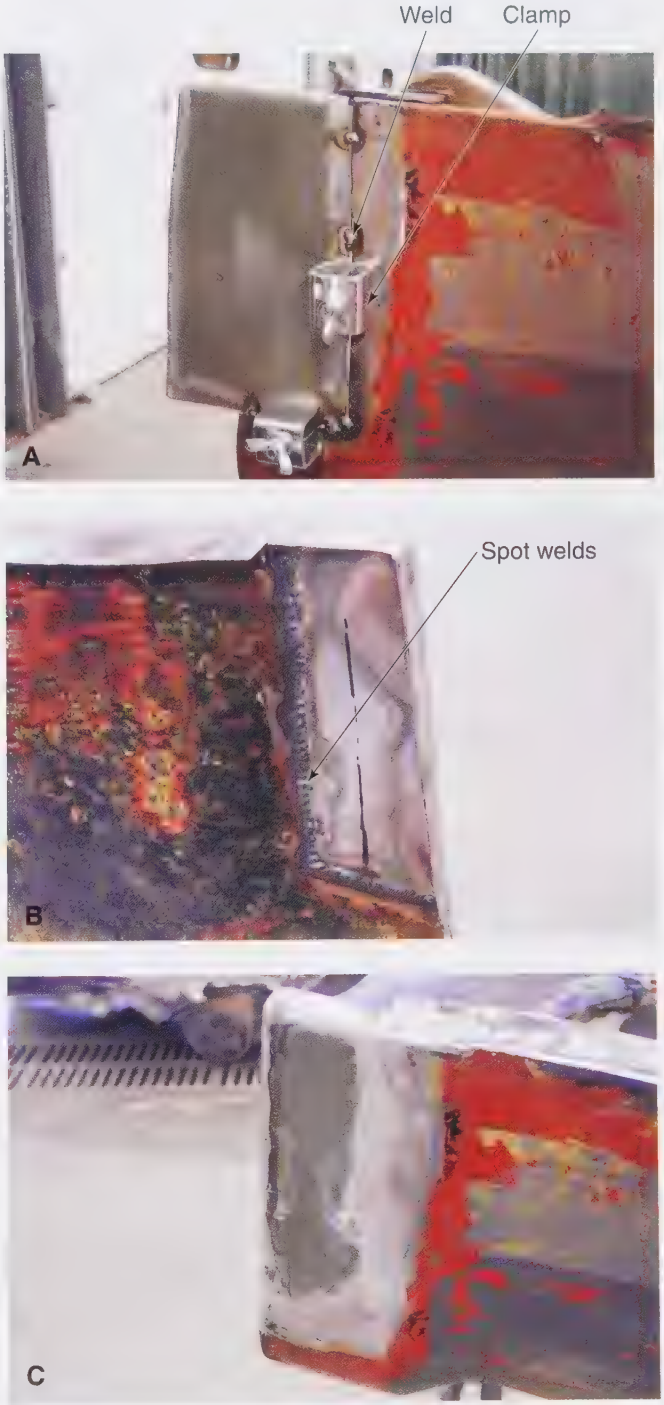


Figure 10-62. *A—Spot welds are placed next to the butt weld clamps. B—Notice how a series of spot welds attaches the patch panel to the fender. C—The welds are ground on the front side of the panel, so no seam is visible.*

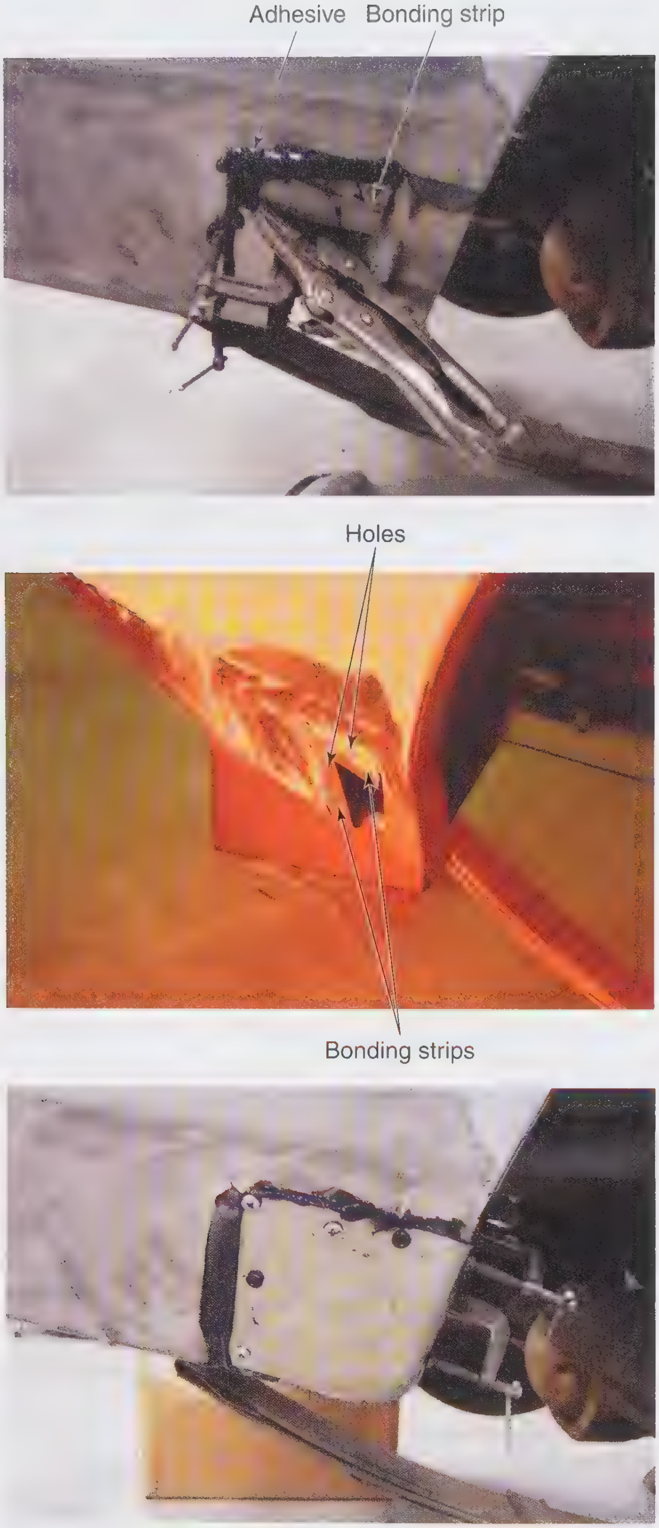


Figure 10-63. *A—The bonding strips are held in place with clamps while the adhesive cures. B— Holes are drilled in the bonding strips so that sheet metal screws can be installed to hold the patch panel while the adhesive cures. C—The patch panel is installed. The sheet metal screws will be removed and the holes filled after the adhesive cures.*

around the edge of the patch panel on the rusted panel. Final cut the panel. If the panel will be welded, use a butt weld as shown in **Figure 10-62**.

Prep the patch panel by removing the paint from its edges. Fit up the patch panel with butt welding clamps. Make the welds as a series of spot welds or short stitch welds. Grind the welds on the outside of the panel.

If the panel will be bonded, remove the paint from the surfaces where adhesives will be applied. Apply adhesive to the bonding strips, position the strips, and hold them in place while the adhesive cures. Fit up the patch panel. Drill holes in the patch panel and the bonding strip for sheet metal screws. Apply adhesive to the bonding strips and position the patch panel. Install sheet metal screws to hold the patch panel in place while the adhesive cures. See **Figure 10-63**. After the adhesive cures, remove the screws, grind the edges of the patch panel and screw holes to a featheredge, and apply adhesive or aluminum body filler.

Summary

- In a full panel replacement, the entire damaged panel is removed from the vehicle at the factory seams and a replacement panel is welded or bonded in place.
- In a splice replacement, the damaged portion of a panel is removed and only a portion of the full replacement panel is installed.
- The first step in any repair is to read the estimate or repair order.
- All damage must be identified before replacing panels. Because most vehicle panels are connected, damage to one panel may extend into adjacent panels.
- The common joints used in panel replacement include the butt joint, sleeve joint, flange joint, lap joint, and semi-butt joint.
- During the rough cutting stage, the damaged panel is removed from the vehicle.
- Before removing spot welds, the technician must decide if the underlying panel can be cut.
- When test fitting the replacement panel on the vehicle, make sure all panel gaps are the proper width and uniform. Once everything lines up correctly, the panel or panels can be final cut.
- Proper preparation of a replacement panel and the existing panel will ensure that the repair is as durable as an undamaged vehicle.
- Replacement panel fit up requires that the panel be installed on the vehicle and clamped or screwed in place.
- Joining involves permanently attaching the

replacement part to the vehicle.
- MIG welding is the most common joining method used in collision repair.
- Bonding involves the use of adhesives to join replacement parts to the vehicle.
- Weld bonding is a combination of squeeze-type resistance spot welding and the use of adhesives.
- Finishing is the last step in panel replacement. Finishing includes dressing the welds, filling weld gaps, and applying rustproofing.

Review Questions

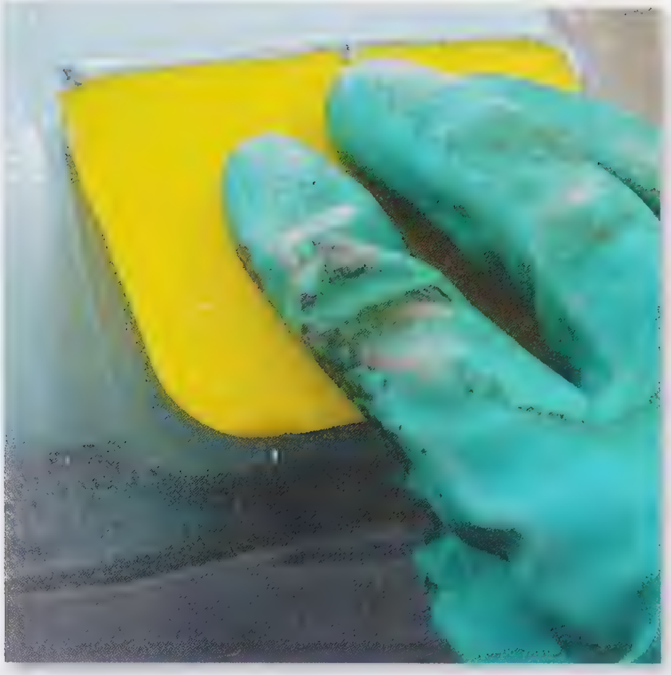
Please do not write in this textbook. Place your answers on a separate sheet of paper.

1. To make a full panel replacement, the replacement panel is attached at the ______ seams.
2. A(n) ______ involves replacing only a portion of the damaged panel.
3. What is the first step in making a welded panel replacement?
4. List five types of panel joints.
5. Explain how to make a sleeve joint.
6. Explain how to make a flange joint.
7. Explain how to mark a cut line on a panel.
8. Quarter panel alignment is adjusted after welding. True or False?
9. The heat of MIG welding will burn the paint off the back of panels. True or False?
10. The back glass must always be removed when splicing a quarter panel. True or False?
11. Explain how to replace an outer wheel house when replacing a quarter panel.
12. On a wraparound-type roof, where are the spot welds located?
13. The three types of roof joints are channel, ______, and ______.
14. Roof panels are usually spliced between the bows. True or False?
15. A bed side should not be sectioned. True or False?
16. Explain how to replace a van side.
17. When replacing a door skin, the hem flange is removed by ______.
18. A window frame on a door is being spliced. If the window frame is wider than ______", a sleeve joint should be made.
19. When folding over the hem flange on a door skin, the bottom flange is folded first. True or False?
20. Explain how to smooth a door skin after it has been replaced.

ASE-Type Questions

1. Technician A says a splice replacement is faster than a full panel replacement. Technician B says a splice replacement is not an acceptable repair method. Who is right?
   (A) A only.
   (B) B only.
   (C) Both A and B.
   (D) Neither A nor B.
2. Technician A says damage to one vehicle panel may extend into adjacent panels. Technician B says a damaged frame rail should be straightened before a replacement panel is installed. Who is right?
   (A) A only.
   (B) B only.
   (C) Both A and B.
   (D) Neither A nor B.
3. Technician A says that when making a butt joint, the panels should be aligned so the gap between them is twice the thickness of the panels. Technician B says that a butt joint should only be used on crowned panels that are less than 6" wide. Who is right?
   (A) A only.
   (B) B only.
   (C) Both A and B.
   (D) Neither A nor B.
4. When preparing a flange joint, the gap between the flange and the edge of the replacement panel should be ______.
   (A) 1/16"
   (B) 1/8"
   (C) 1/4"
   (D) 1/2"
5. Which of the following joints is the simplest to make?
   (A) Lap joint.
   (B) Flange joint.
   (C) Sleeve joint.
   (D) Butt joint.
6. Technician A says that rough cutting is not required during full panel replacement. Technician B says that when performing a splice repair, the replacement panel cannot be test fit to the vehicle until the damaged panel is removed. Who is right?
   (A) A only.
   (B) B only.
   (C) Both A and B.
   (D) Neither A nor B.

7. Which of the following tools can be used to remove spot welds?
   (A) Hole saw.
   (B) Chisel.
   (C) Torch.
   (D) Grinder.
8. A replacement panel is being fit up. Technician A says the panel can be held in place with clamps. Technician B says the panel can be held in place with screws. Who is right?
   (A) A only.
   (B) B only.
   (C) Both A and B.
   (D) Neither A nor B.
9. Technician A says that MIG welding is the most common joining method used in collision repair. Technician B says that nonstructural panels can be joined with structural adhesive. Who is right?
   (A) A only.
   (B) B only.
   (C) Both A and B.
   (D) Neither A nor B.
10. Which of the following is not a panel replacement finishing operation?
    (A) Dressing the welds.
    (B) Filling the weld gaps.
    (C) Spraying the weld area with epoxy primer.
    (D) Making the flange joint.
11. A quarter panel must be replaced. Technician A says the parts attached to the quarter panel should be removed. Technician B says quarter panels are commonly spliced. Who is right?
    (A) A only.
    (B) B only.
    (C) Both A and B.
    (D) Neither A nor B.
12. A roof is being replaced. Technician A says the front and rear glass must always be removed before replacing the roof panel. Technician B says that roof panels cannot be spliced in the conventional manner and that the silicon-bronze joint must be used as an installation point. Who is right?
    (A) A only.
    (B) B only.
    (C) Both A and B.
    (D) Neither A nor B.
13. Technician A says that most rear body panels are spot welded to the quarter panels, trunk floor, and rear frame rails. Technician B says that most replacement rear body panels are bonded to the vehicle with structural adhesive. Who is right?
    (A) A only.
    (B) B only.
    (C) Both A and B.
    (D) Neither A nor B.
14. The bed side of a pickup truck consists of all of the following EXCEPT:
    (A) the wheel house.
    (B) a portion of the bed floor.
    (C) inner and outer walls.
    (D) a portion of the cab.corner.
15. Technician A says a pickup truck bed side is commonly sectioned. Technician B says that difficult-to-install bed sides should be welded rather than bonded. Who is right?
    (A) A only.
    (B) B only.
    (C) Both A and B.
    (D) Neither A nor B.
16. Technician A says a cab corner is similar to the quarter panel on a car. Technician B says that when replacing a cab corner, a portion of the replacement panel can be used to make a sleeve. Who is right?
    (A) A only.
    (B) B only.
    (C) Both A and B.
    (D) Neither A nor B.
17. Which of the following joint types is used when replacing a van side?
    (A) Sleeve joint.
    (B) Flange joint.
    (C) Lap joint.
    (D) Butt joint.
18. A door skin is being replaced. Technician A says the damaged door should be aligned before it is removed. Technician B says the hem flange around the edge of the door can be removed with a grinder. Who is right?
    (A) A only.
    (B) B only.
    (C) Both A and B.
    (D) Neither A nor B.
19. A new door skin is being fit into place. Technician A says the hem flange should be folded using a door skin hammer and a 9" hard-plastic sanding block. Technician B says that the folded hem flange should line up with paint edge that was exposed when the damaged door skin was removed. Who is right?
    (A) A only.
    (B) B only.
    (C) Both A and B.
    (D) Neither A nor B.
20. A patch panel is being installed over a rusted area. Technician A says to rough cut the rust-damaged panel before final cutting the patch panel. Technician B says that patch panels can be bonded in place. Who is right?
    (A) A only.
    (B) B only.
    (C) Both A and B.
    (D) Neither A nor B.



Chapter 11

Plastic Repair

Objectives

After studying this chapter, you will be able to:

- Describe the various ways to classify plastics.
- Recognize tools and materials used in plastic repair.
- Summarize the basic steps used in plastic repair.
- Describe procedures for repairing specific types of plastic damage.

Technical Terms

active shaping
adhesion
adhesion promoter
adhesives
backer
beveling
binding
bonding
cure
die grinder
fabricating
fiberglass resin
finishing
float test
hardener
hot-air welder
ISO code
mesh
passive shaping
plastic welder
plastic welding
polymer
reinforcement
texturing paint
V-groove
welding filler rod
work time

Introduction

Plastics are used extensively in late-model vehicles. Exterior applications include body panels, bumper covers, fender extensions, grilles, trim pieces, and other components. Interior applications include steering wheels, door panels, and instrument panels. Because plastic is lighter than metal, plastic parts help improve vehicle efficiency by reducing vehicle weight. Plastic parts are less susceptible to corrosion and minor dents than metal parts. They are often more economical to manufacture than their metal counterparts.

All plastics are polymers. A ***polymer*** is a molecule made up of many units called monomers. The monomers are joined together in a repeating pattern. The monomers that make up the polymer determine the type of plastic. An example of a monomer is olefin.

Additives are mixed with plastic polymers to achieve desired properties. For example, depending on additives used during manufacture, plastics can be flexible enough to bend 180° without damage, rigid like sheet metal, or have any degree of flexibility in between.

All plastics are molded into the desired shape. Some plastics have a texture. See **Figure 11-1**. Other plastics are smooth. Some plastic parts are painted the same color as the vehicle, while others are painted a contrasting color, such as black. Plastic parts are sometimes painted two colors, one color in the smooth area and a different color in the textured area. See **Figure 11-2**. Some plastics are molded in color rather than painted.

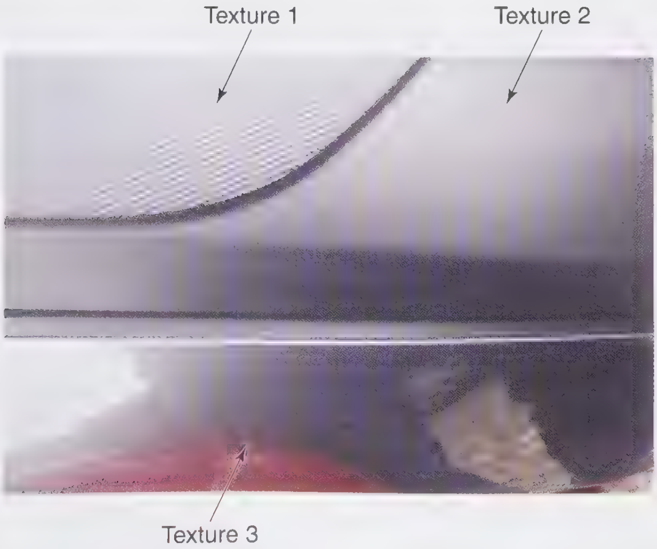


Figure 11-1. *Textured plastic bumpers can be found on many late-model vehicles. Note that there are three different textures on this bumper cover.*

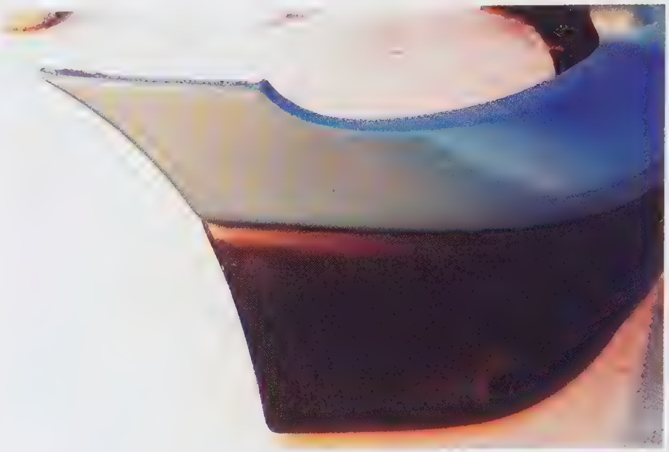


Figure 11-2. *The textured portion of this bumper is on the bottom and the smooth, painted portion is on the top.*

This chapter explains how to repair many types of automotive plastics. The most commonly repaired plastic parts are bumpers. The composition of the plastic, as well as the cost of repair, must be considered when determining whether a part should be repaired or replaced. Some plastic parts should not be repaired, such as chrome-plated plastic grilles. The plastic itself can be repaired, but not the chrome. Other types of plastic can be repaired, but the cost of repair is greater than the cost of replacement. An example of this situation is a textured, molded-in-color bumper. A torn bumper of this type can be repaired, but the retexturing and paint adhesion difficulties would make the labor cost of the repair greater than the cost of a new part. Always consider the cost of replacement versus the cost of the repair when deciding whether or not to repair a plastic part.

The word ***adhesion*** will be used throughout this chapter. Adhesion in plastic repair means that a repair material will stick (adhere) to the plastic surface. Poor adhesion is a common problem in plastic repair. **Figure 11-3** shows an example of poor adhesion. A repair material has been applied to a plastic part, but the material does not stick. The technician can peel the cured material off the repair area. The reasons for poor adhesion include:

- Surface contamination preventing a bond between the repair material and the plastic.
- Smooth plastic surface not allowing the repair material to adhere.
- Surface chemistry of plastic not allowing the repair material to adhere.

Lack of adhesion is the most frequently encountered problem when repairing plastic. Avoid adhesion problems by thoroughly cleaning plastic parts at the beginning of the repair. Also thoroughly sand the repair area. Certain plastics must be chemically treated before the repair material is applied.

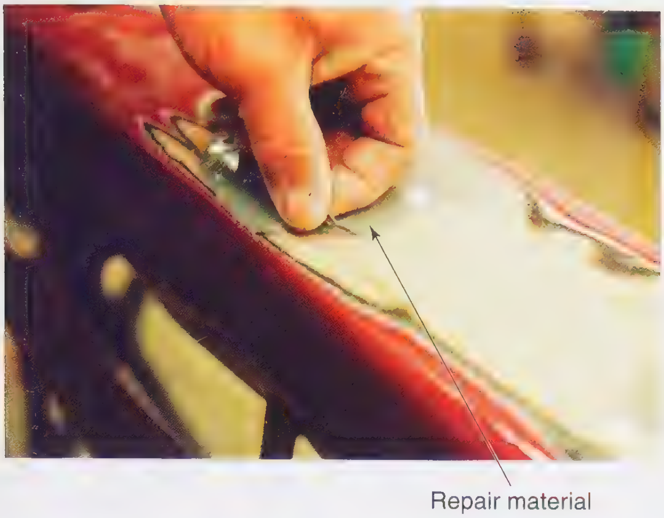


Figure 11-3. *This is poor adhesion. The plastic repair material can be peeled off of the bumper.*

Classifying Plastics

For the purposes of this textbook, we will consider three ways to classify plastics: rigidity, capacity to be welded, and chemical composition. Automotive plastics can be described as rigid, semi-rigid, or flexible. This classification system is somewhat subjective. A rigid plastic will not bend or flex without breaking. A semi-rigid plastic will bend somewhat without breaking, but it cannot be bent 180° without breaking. A flexible plastic can be bent 180° without breaking.

Bumper covers are often made out of flexible plastic because these covers are the most commonly damaged parts on a vehicle. A minor impact on a bumper cover that causes the cover to flex may not cause any permanent damage.

Another way to classify the types of plastic on a vehicle is the capacity of the material to be welded. Some plastics, which are known as thermoplastics, can be heated, even to melting temperatures, and retain all their original characteristics. Thermoplastics can be welded with special plastic welding equipment because the heating and melting does not alter the plastic. Thermoset plastics burn rather than melt when heated. Heating destroys thermoset plastics. Damaged thermoset plastics can be repaired with fillers and adhesives, but they cannot be welded. The last method used to classify automotive plastics is based primarily on chemical composition.

Figure 11-4 lists the types of automotive plastics commonly encountered in auto body repair. The chart is divided into thermoset plastics and thermoplastics. The R stands for rigid plastic, the SR for semi-rigid plastic, and the F for flexible plastic. Notice that some thermoset plastics are flexible. Urethane plastics are easy to identify because the raw, unpainted plastic is yellow. Look on the back side of a bumper cover to see the color of the unpainted plastic. Note that although RRIM and RIM are urethane plastics, they are identified by their manufacturing process, reaction injection molding, rather than their chemical composition. Rigid plastics like SMC and fiberglass will not stretch from collision forces, but flexible polyurethane will stretch. The repair of polyurethane may involve heating to reshape stretch damage. Most thermoplastics are semi-rigid.

Some of the plastics, such as Pulse, Xenoy, and GTX, are composites of different types of plastics. Composites can be designed to produce desired characteristics such as strength or flexibility. Generally plastic parts on a vehicle are lighter than a comparable steel part. TEO is commonly used for bumper covers because it can be easily recycled.

Some thermoplastics contain the chemical *olefin*. Olefin-containing plastics, along with polypropylene, have a slick or greasy feel. The surface of olefin containing plastic must be treated with an adhesion promoter before adhesives are applied. Without adhesion promoter, the adhesives will not stick to the olefin-containing plastic.

Tools and Materials

Plastic repair involves many of the same tools and materials used in metal panel repair, as well as a few tools and materials unique to plastic repair. This section details the tools and materials unique to plastic repair. These include a die grinder, plastic welder, rigid and flexible repair material, adhesion promoter, mesh, and fiberglass.

Die Grinder

An air-powered die grinder and bit are shown in **Figure 11-5**. The ***die grinder*** rotates the bit at high speeds. This tool is used to cut a V-groove in the plastic part being repaired. A V-groove increases the contact area for the repair material (filler rod or adhesive).

Plastic Welder

An airless ***plastic welder*** and related materials are shown in **Figure 11-6**. The welder has an adjustable heat setting so it can be used to melt various types of plastic filler rods. The welder is warmed up by setting it to preheat. Then it is set to the melt temperature of the filler rod. **Figure 11-7** shows the melt temperatures for different types of filler rod.

Types of Automotive Plastic

	Rigidity	ISO code or symbol	Name	Type of part	Repair method
THERMOSET	R	SMC	sheet molded compound	hood, header, hatch, fender	filler and adhesives
	R	UP, FRP	fiberglass	running boards	filler and polyester resin
	F	PUR	polyurethane	bumper cover, ground effects	adhesives and binding
	F	RRIM, RIM	reinforced reaction injection molding	fender	adhesives and binding
THERMOPLASTIC	SR	PA	nylon	radiator tanks, trim	welding
	SR	ABS	acrylonitrile butadiene styrene	grilles, Interior trim	welding and glue
	SR	HDPE	high density polyethylene	overflow tanks, fender liners	welding
	SR	PC+ ABS	pulse	Saturn door skins	welding or adhesives
	SR	PC+ PBT	Xenoy	bumpers	welding or adhesives
	SR	PPO+ PA	GTX	fenders	welding or adhesives
	F	PP	polypropylene	fender liners radiator shrouds	welding
	F	TPO	thermoplastic olefin	bumper covers ground effects	welding and adhesives
	F	TEO	thermo elastomeric olefin	bumper covers	welding and adhesives
	F	PP+ EPDM		bumper covers	welding and adhesives
	F	PE	polyethylene	bumper covers	welding

Figure 11-4. *Common automotive plastics are listed in this chart.*

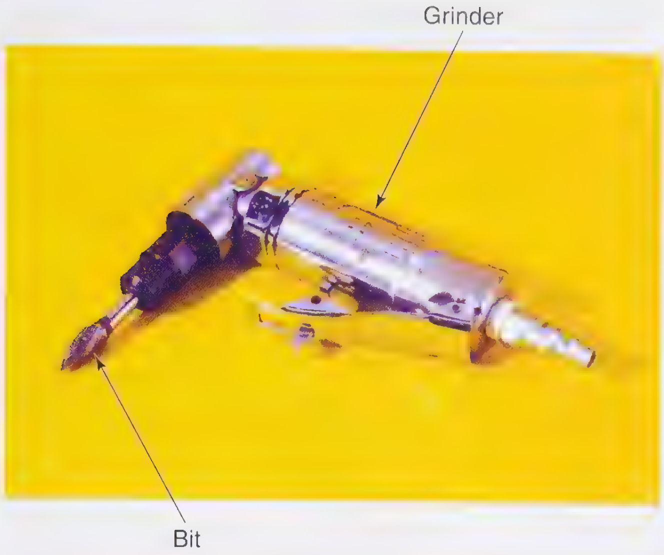

Grinder
Bit

Figure 11-5. *This die grinder and bit are used to make a V-groove in plastic.*

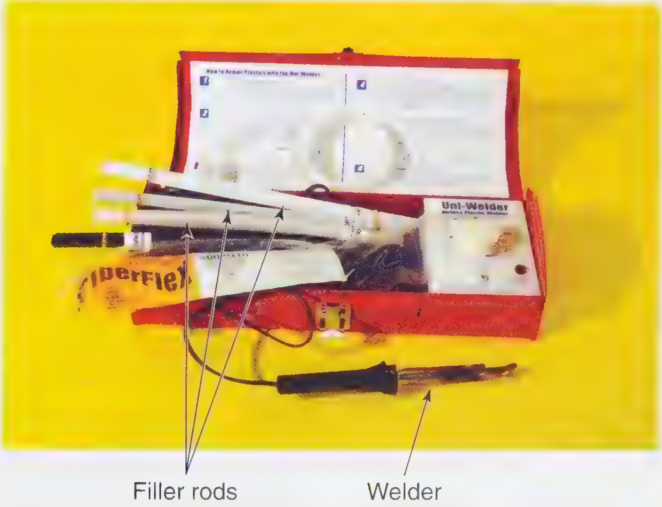
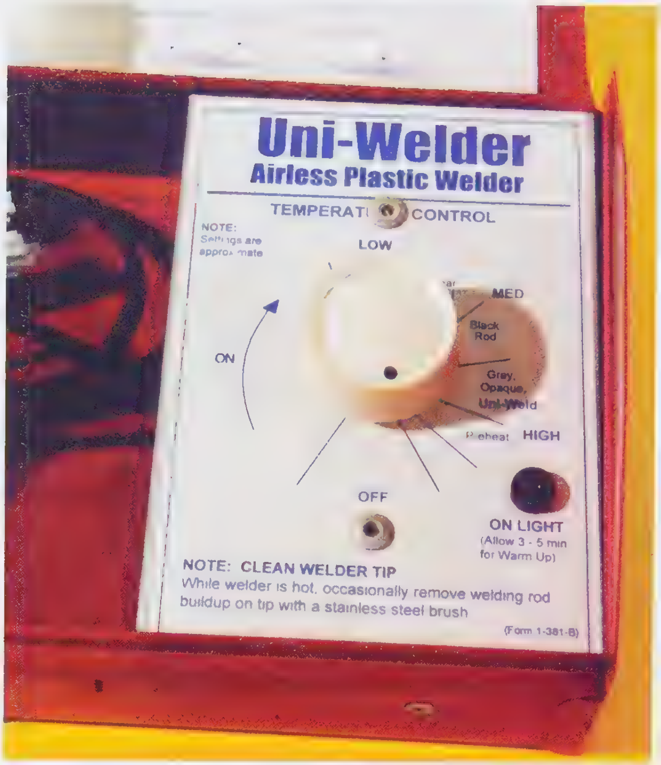

Uni-Welder
Filler rods
Welder

Figure 11-6. *An airless plastic welder kit consists of the welder and various rods.*

A shoe is screwed into the base of the welder. The two types of shoes used in plastic welding are the flat shoe and the feed shoe. These are shown in **Figure 11-8**. The flat shoe is used to melt and shape the filler rod. With the feed shoe, round filler rod is fed into the hole in the shoe and melted. The melted rod passes out of the bottom of the shoe and contacts the repair area of the plastic part.

WARNING

The welder's shoe is hot and, therefore, should not be allowed to contact anything flammable. When the welder is not in use, place it in a holder as shown in Figure 11-9.


Uni-Welder
Airless Plastic Welder
TEMPERATURE CONTROL
NOTE: Settings are approximate
LOW
MED
Black Rod
Gray, Opaque, Uni-Weld
Preheat
HIGH
ON
OFF
ON LIGHT (Allow 3 - 5 min for Warm Up)
(Form 1-381-B)

NOTE: CLEAN WELDER TIP
While welder is hot, occasionally remove welding rod buildup on tip with a stainless steel brush

Figure 11-7. *Different types of plastic require different welding temperature settings. This airless plastic welder has adjustable heat setting for various types of plastics.*

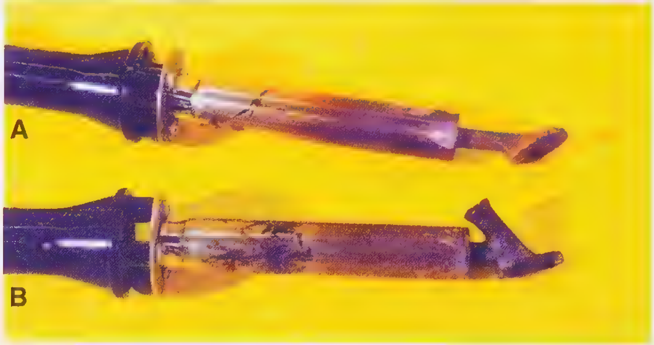


Figure 11-8. *A—Flat shoe weld tip. B—Feed shoe weld tip.*

Welding filler rod should be matched to the type of plastic being repaired. For example, ABS rod should be used on an ABS part and urethane rod on a urethane part. Universal rod is also available and will adhere to any type of plastic. The plastic type does not necessarily have to be identified when using universal rod.

A hot-air plastic welder is shown in **Figure 11-10**. A ***hot-air welder*** is a small heat gun. Hot air from the gun's discharge tip heats the filler rod and the plastic

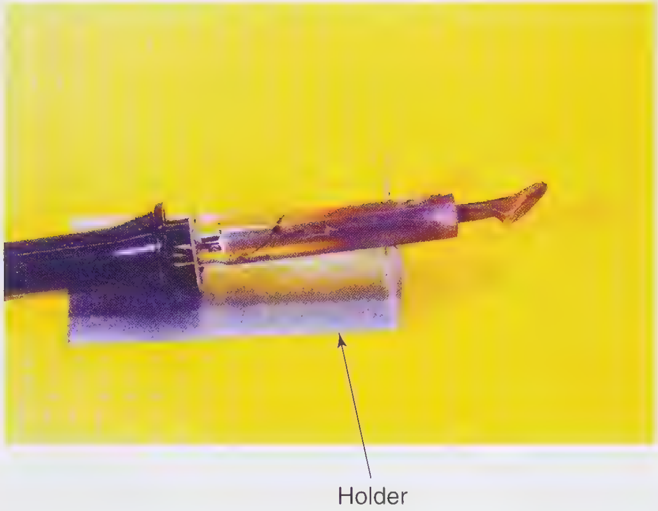


Figure 11-9. *A misplaced hot welding tip can cause injury or damage. Keep the welder on the stand when not in use.*

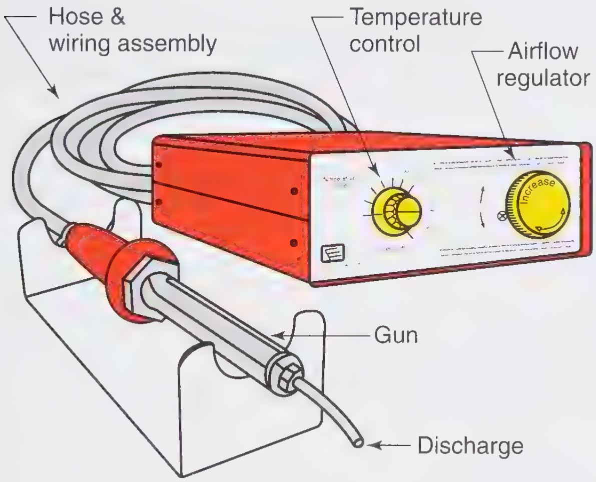


Figure 11-10. *A hot-air welder heats compressed air to melt plastic and filler rod. This hot-air welder can use compressed air or nitrogen gas. (Urethane Supply Co.)*

part at the same time, fusing them together. The hot-air welder shown in the illustration uses either compressed air from an air line or compressed nitrogen gas from a tank. The oxygen in the compressed air produces oxidation in the weld, creating a slightly weaker weld than a weld made with nitrogen gas. A hot-air welder heats a larger area than an airless welder and requires more skill to operate. When a long weld is required, a hot-air welder can make the weld faster than an airless welder. The hot-air welder's discharge tip is larger than an airless welder's feed shoe. This may limit the usefulness of a hot-air welder in confined areas.

Adhesives

Adhesives are two-part repair materials. When mixed together, the two parts undergo a chemical change and ***cure***, or harden. The chemical change that causes curing results from the reaction between the molecules in the two parts of the adhesive. The adhesive has a ***work time***, which is the number of minutes between mixing and curing. As the curing takes place, the mixed adhesive will stiffen and gradually become unworkable. Once the adhesive has cured, it has full strength and adhesion, and it can be sanded. Depending on the type of material used, the cured repair material can be either flexible or rigid.

An example of a hand-mixed adhesive is shown in **Figure 11-11**. With this type of adhesive, equal amounts of the black and the white material are mixed together. The dark gray mixture is then applied with a filler spreader. A tube-mixed adhesive is shown in **Figure 11-12**. With this adhesive, an applicator gun and a mixing tube are needed. As the applicator gun is triggered, the two components are forced together in the mixing tube. By the time the components reach the end of the tube, they are thoroughly mixed. However, you should discard the first 2" of adhesive because it may not be properly mixed. The adhesive is applied to the damaged area directly from the tube. Adhesives can be used to fill gouges or to attach reinforcements.

WORKING SMART

Plastic repair materials are available from a number of different vendors. Each vendor provides written guidelines for the use of its product. Always read the vendor's guidelines before beginning the repair. Always follow the vendor's guidelines, even if they deviate from the instructions given in this chapter.

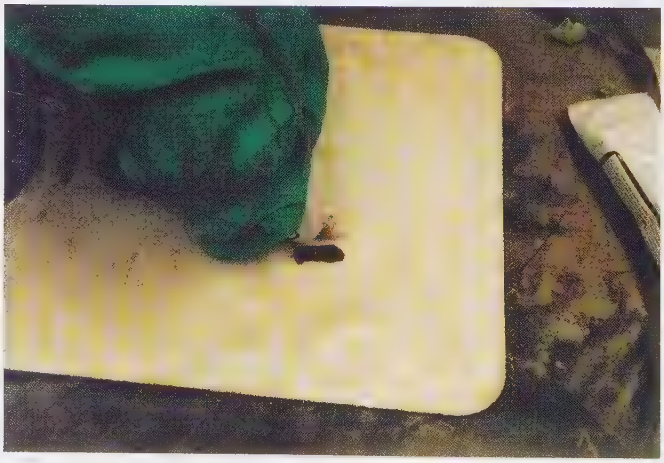


Figure 11-11. *When mixing plastic repair material from tubes, squeeze out equal lengths of each component.*

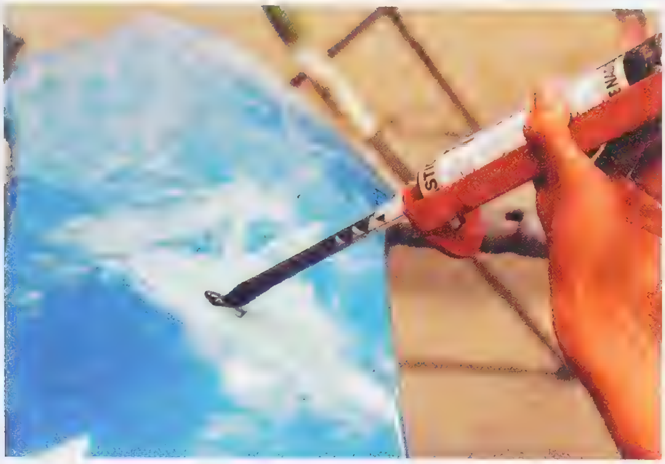


Figure 11-12. *A mixing tube combines the two adhesive components. The two separate components enter the tube and they are combined into a uniform mixture by the spirals in the tube.*

Adhesion Promoter

A spray ***adhesion promoter*** is shown in **Figure 11-13**. This chemical is used before applying adhesives to olefin-containing plastics. The adhesion promoter changes the chemistry of the olefin plastic surface, allowing adhesives to stick. Adhesion promoter may also be applied with a brush or dauber. The adhesive promoter must be applied before the adhesive.

Sanding will remove the layer of adhesion promoter. If the adhesive is sanded but more adhesive is required to fill, additional adhesion promoter must be applied to the repair area.

Figure 11-13. *Adhesion promoter allows repair material to adhere to plastic.*

Some flexible plastic repair materials are made with adhesion promoters premixed with the material. A separate adhesion promoter is not required. This greatly simplifies the plastic repair process. These types of plastic repair materials will adhere to any flexible plastic. Read and follow the instructions on the tube of plastic repair material.

Mesh

Mesh is used as reinforcement when making plastic repairs. Plastic and metal mesh is shown in **Figure 11-14**. The steel mesh can be melted into the plastic when welding. It strengthens the repair area. A plastic mesh can be used with adhesives, again strengthening the repaired area. The plastic mesh is laid down and the adhesive is applied over it.

Fiberglass

Fiberglass resin and ***hardener***, as well as fiberglass cloth or mat, are used to make repairs in cracked or broken fiberglass parts. See **Figure 11-15**. Fiberglass cloth and mat are shown in **Figure 11-16**. The mat has fiberglass strands in random directions, while the cloth has strands that are arranged in a uniform pattern. The fiberglass cloth or mat acts as a reinforcement for the resin and hardener mixture.

The liquid resin and hardener are mixed together in the proper amounts and stirred. The cloth or mat is saturated with the resin/hardener mixture. When the resin/hardener cures, the repair is quite rigid. Heat from a heat lamp or heat gun will help reduce the cure time.

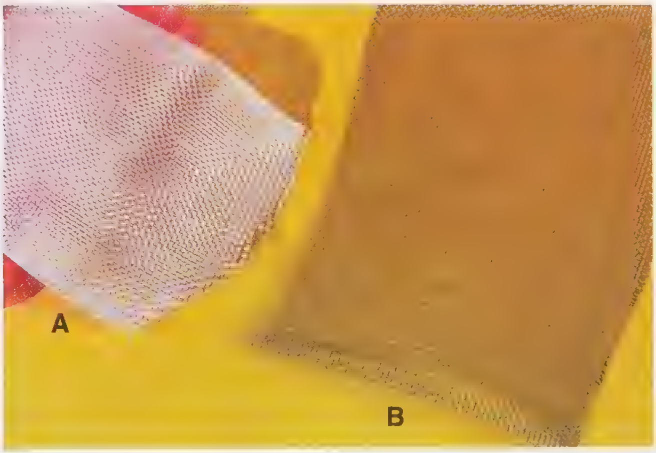


Figure 11-14. *A—Plastic mesh. B—Aluminum mesh.*

NAPA
BALKAMP
765-1286
fiberglass
RESIN
WITH HARDENER
USED TO REPAIR
AUTOMOTIVE
MARINE
INDUSTRIAL
HOME & FARM
CAUTION.
CONTENTS 128 FL OZS (ONE GALLON)
bondo
LIQUID HARDENER
No 411

Figure 11-15. *Fiberglass resin and hardener are combined with fiberglass mat or cloth.*

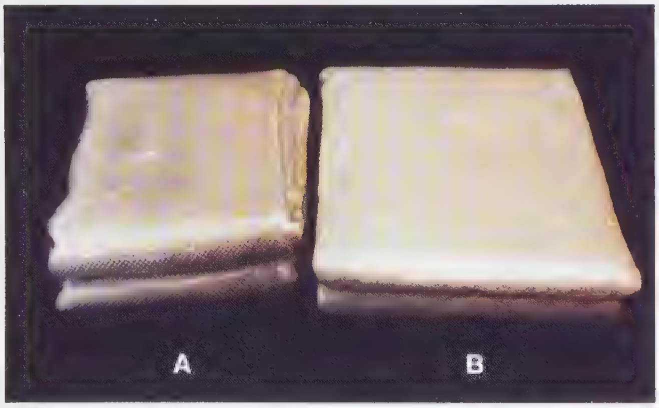


Figure 11-16. *A—Fiberglass cloth. B—Fiberglass mat.*

Plastic Repair Steps

Many of the steps in repairing automotive plastic are the same as repairing sheet metal. In most cases, plastics are repaired in the following sequence:

1. Read the estimate.
2. Remove the damaged part.
3. Clean the repair area.
4. Identify the plastic to be repaired.
5. Plan the repair.
6. Align the damaged parts.
7. Make the repair.

The following sections detail the major steps in plastic repair. Not all steps are needed for every repair.

Read the Estimate

The first step in any repair is to read and understand the estimate or work order. The damage is usually obvious but a vehicle may have damage that is not listed for repair on the estimate and will not be paid for by the customer. Understand what repairs must be made before proceeding.

Remove the Damaged Part

Many plastic repairs require access to both sides of the part. The plastic part, such as a bumper cover, must be removed. Also many shops refinish bumper covers off the vehicle, so the part will need to be removed for painting. Repair of a gouge, scratch, or other minor damage will not necessarily require the removal of the plastic part, and some shops may refinish the part on the vehicle.

There are two ways to remove a bumper cover. The first way is to remove the bumper cover from the reinforcement. The reinforcement remains attached to the vehicle. Usually the bumper cover is secured with bolts, screws, or plastic rivets. Removal of these fasteners allows the bumper cover to be lifted off the reinforcement. The other way to remove the bumper cover is to unbolt the reinforcement from the vehicle and remove the bumper cover and reinforcement as an assembly. The reinforcement is heavy, causing the assembly to be awkward when moving or positioning. If access to both sides of the bumper cover is required, the reinforcement may be in the way and will need to be removed.

WORKING GREEN

In an effort to reduce the number of plastic parts that end up in landfills, some collision repair shops are installing refurbished OEM bumper covers rather than using new OEM or aftermarket covers. The refurbished covers are often processed at companies that specialize in restoring damaged covers to like-new condition. Companies that refurbish covers often buy damaged covers, or cores, from collision repair shops.

Other plastic parts, such as fender liners, radiator shrouds and ground effects are held in place with screws, bolts, or plastic rivets. Remove the fasteners and take the part off the vehicle. Plastic body side moldings and some ground effects may be attached by double-sided tape. Double-sided tape can be cut off with a utility knife.

Clean the Repair Area

For proper adhesion, both sides of the plastic part must be clean before attempting repairs. First wash the part with soap and water. This process will remove water-soluble contaminants. Next, spray a plastic cleaner on the part. Wipe the cleaner in one direction only, using a clean area of the cloth with each wipe. See **Figure 11-17**.

CAUTION

Do not use wax and grease remover or lacquer thinner when cleaning plastic parts. These solvents may be absorbed by the plastic and cause an adhesion problem.

Identify the Plastic to Be Repaired

There are several methods used to repair plastics. A critical step in each method is to identify the plastic. The following is a list of ways to identify plastic:

- Many types of plastic have an ***ISO code*** molded into the part. See **Figure 11-18**. Sometimes the code will be surrounded by an oval or square.
- Collision repair manuals will list the types of plastics used on various vehicle components. To identify a type of plastic, look up the part on the list. This information is also available on the Internet from repair material manufacturers.
- A critical difference in flexible plastics is the addition of olefin. A plastic that contains olefin has a surface chemistry that prevents an adhesive from binding. **Figure 11-19** shows a grinder used on the back side of a bumper to determine if the plastic contains olefin. A slow rotation speed is used. If the plastic melts and smears, the plastic contains olefin. If the plastic grinds dry, it does not contain olefin.

Figure 11-17. *Thorough cleaning is essential on all plastic repairs.*

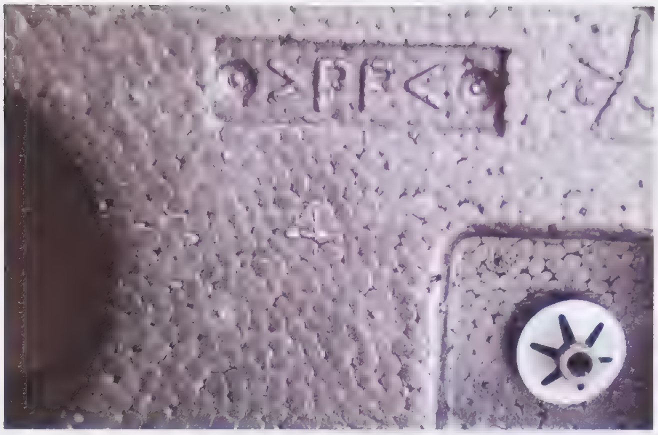


Figure 11-18. *The ISO code for this impact absorber is PP, or polypropylene. Notice the code between the > and < symbols.*

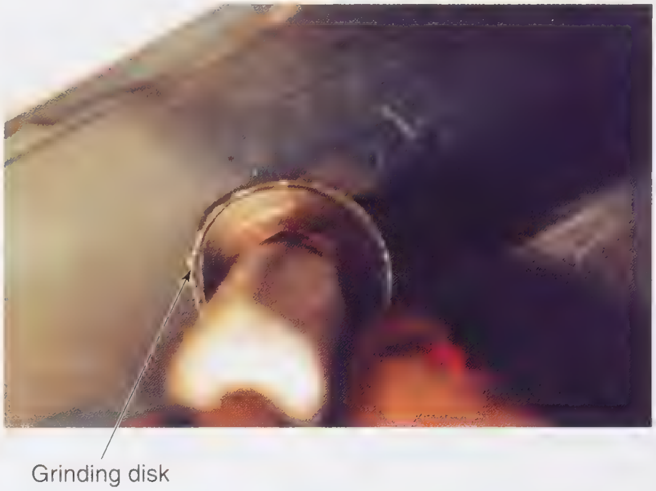


Figure 11-19. *Grinding on the back side of an unknown plastic will determine if the part contains olefin. Melting and smearing indicates the presence of olefin adhesive over the mat.*

- A ***float test*** will determine if an unknown flexible plastic contains olefin. Cut off a sliver of plastic. Immerse the plastic in a container of water. If the plastic floats, it contains olefin. Plastic that sinks does not contain olefin.

Identification is a crucial step in plastic repair. Once the plastic part has been identified, the proper repair process can be determined.

Plan the Repair

The estimate or repair order will list what must be repaired. In planning the technician uses what must be repaired, from the estimate, and the type of plastic, from identification, to determine how to make the repair. Thinking through the repair and anticipating problems will avoid setbacks and make the job quicker and easier.

Align the Damaged Parts

Damaged plastic must be aligned before adhesive or welding repairs can be made. On some types of plastic, aluminum body tape is strong enough to hold the damaged part in its proper place. See **Figure 11-20**. However, some damage may require a stronger hold. In this case, paint sticks and clamps can be used as shown in **Figure 11-21**. Keep the clamps out of the repair area so the repair material will not get on the clamps. The repairs are started on the inside of the damaged part. Once the inside is repaired, the alignment material can be removed.

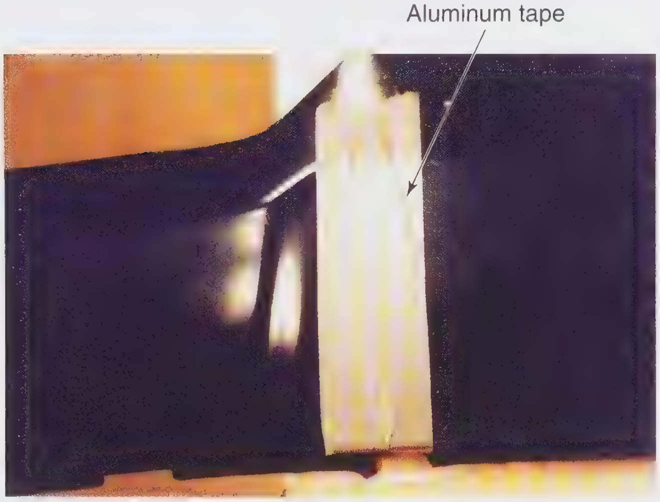


Figure 11-20. *Aluminum body tape can be used to align broken plastic.*

The most common alignment problem is a difference in height. If not properly aligned, one side of a tear may end up higher than the other. Sanding and feathering may be used to correct this problem. However, it is better to align the edges of a tear before starting the repair. Shattered fibers in SMC and fiberglass may make alignment difficult. See **Figure 11-22**. If this is the case, use a hacksaw blade to cut through the fibers. This will allow the edges to be aligned.

Flexible plastic will generally spring back into position once a force is removed. Flexible plastic can be stretched and dented, as shown in **Figure 11-23**. A dent is most likely found in a curved, ribbed, or otherwise less flexible area of a part. As on sheet metal, the folds of a plastic dent are stronger than an undamaged section. The dent can be removed with heat. Heating softens the folds of the dent and removes the stretch. This will allow the plastic to spring back into shape.

In ***passive shaping***, the damaged part is placed in the heated spray booth. The 140°F heat in the booth may be enough to reshape the part. The part may also be placed in the bright sunlight for reshaping.

In ***active shaping***, the technician heats the part. The heat source can be a heat gun or a heat lamp. Then using a suitable tool, the softened area is shaped with the tool. Next, the softened area is cooled with a wet rag. The procedure for active shaping is as follows:

1. Obtain a tool to shape the heated area. The tool shape should match the undamaged shape of the repair area. If the repaired shape is rounded, the tool should be rounded, like a screw driver handle or high-crown dolly. If the repaired shape is flat, use a paint stick to shape the damaged area.

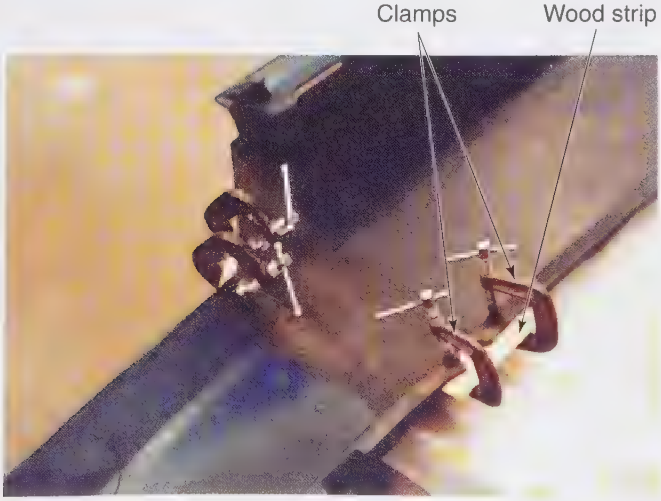


Figure 11-21. *This plastic header panel is broken into two pieces. Small clamps and paint sticks are used to align the edges. Body tape is used in the center.*

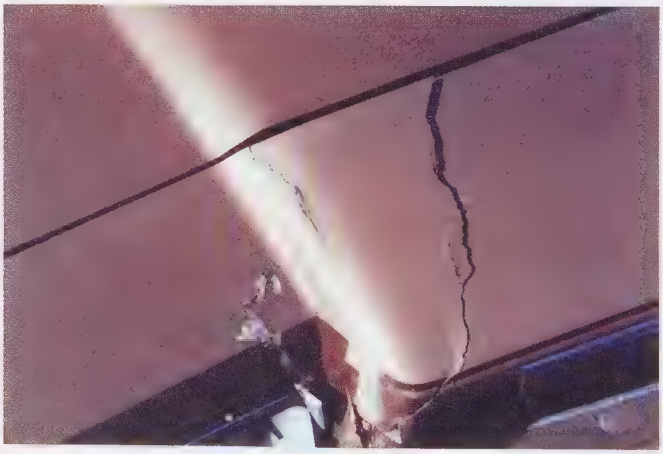


Figure 11-22. *Cracked fiberglass may show fiber misalignment. Cut the fibers so the panel can be aligned.*

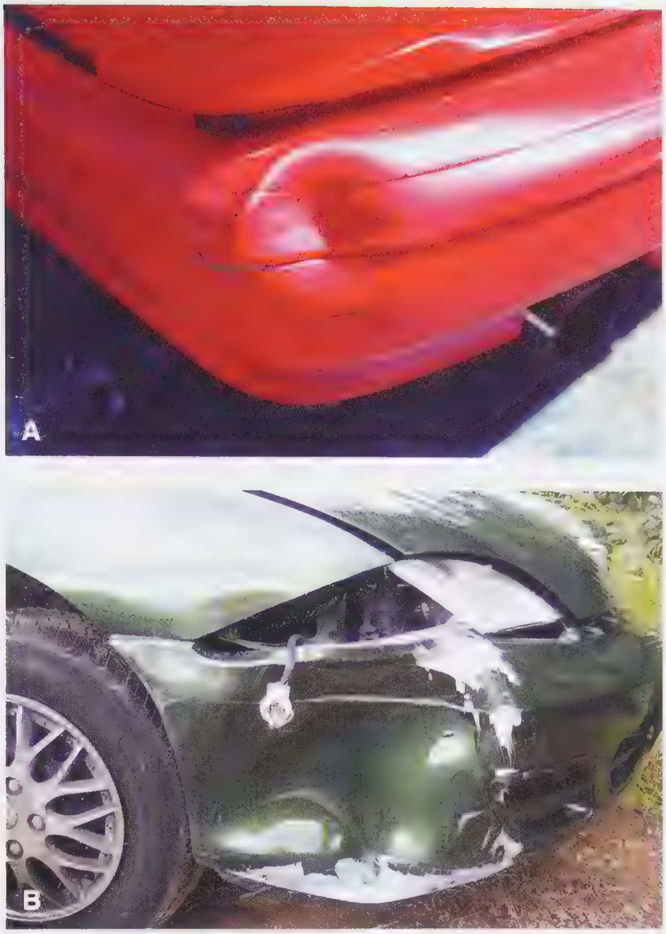


Figure 11-23. *A—The dent in this bumper cover can be removed by heating. B—The side impact stretched the bumper cover at the reinforcement. Heating will reshape this bumper cover.*

2. Heat the outside of the part with a heat gun or heat lamp. Heat the area evenly by moving the heat source around the dent. When the back side of the part is too warm to touch, it is ready for shaping.
3. Use the tool to push the dent out and move the plastic to the right location. Do not overextend the area that is being pushed out.
4. Once the plastic is in the right place, cool the repair with a wet rag. This will lock the location in place.
5. Repeat this procedure if necessary.

Make the Repair

The next step in the repair process is to make the actual repair. The following sections explain some of the common repair procedures. Repair procedures used will differ depending on the type of material damaged and the extent of the damage.

Reinforcement

Reinforcement is steel or plastic mesh used to make a repair stronger. Steel mesh reinforcement is used for welded or bonded repairs. Plastic mesh, as well as fiberglass mat or cloth, can be used for adhesive repairs. A backer can also be used for adhesive repairs. A ***backer*** is a piece of plastic that is the same type of material as the damaged part. The backer should have the same shape as the repair and will help align the repair area. Usually, the backer is cut out of a scrap bumper or a part similar to the part being repaired. All paint should be sanded off the backer. A backer is thicker than other types of reinforcements. If a bumper has a support directly behind the repair area, a backer repair may cause the bumper to protrude too far. In cases like this, mesh or fiberglass should be used as reinforcement. All reinforcements should extend out at least 1" from the edge of the damage. See **Figure 11-24**.

When using steel mesh, the plastic is melted around the mesh as shown in **Figure 11-25**. For adhesive repairs, the repair material is applied to the damaged area and then the mesh, fiberglass, or backer is applied to the area. With mesh and fiberglass, additional repair material is applied on top of the reinforcement. This can be difficult to do. The mesh or fiberglass must be held in place and the repair material applied with a spreader. **Figure 11-26** shows how this procedure is accomplished. On most repairs, one layer of reinforcement is adequate.

V-Grooving

A ***V-groove*** is used to increase the contact surface area of the adhesive or weld repair. A larger surface area makes a stronger repair. The V-groove also makes a featheredge that will hide the repair.

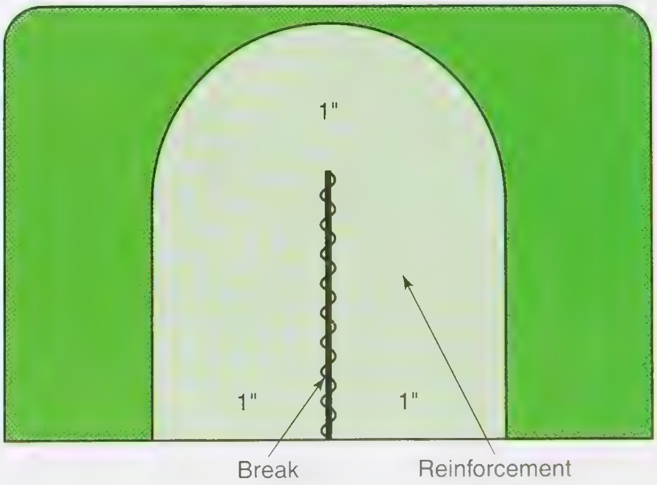


Figure 11-24. *The reinforcement should extend at least 1" from the edges of the damage.*

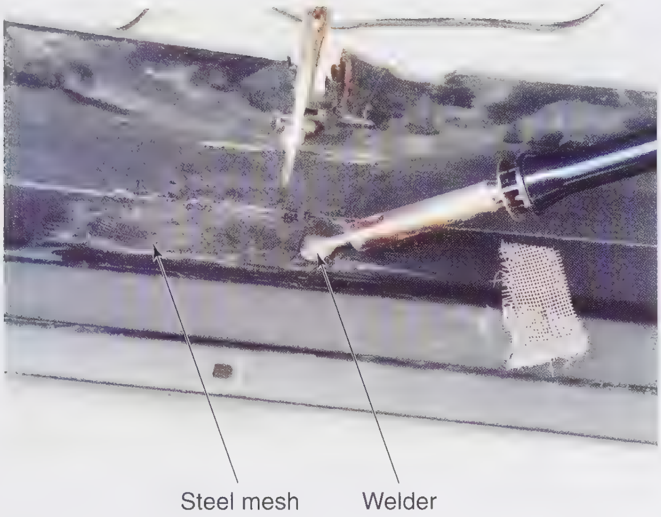


Figure 11-25. *The flat shoe of the welder is used to heat the aluminum mesh. The heated mesh melts into the plastic.*

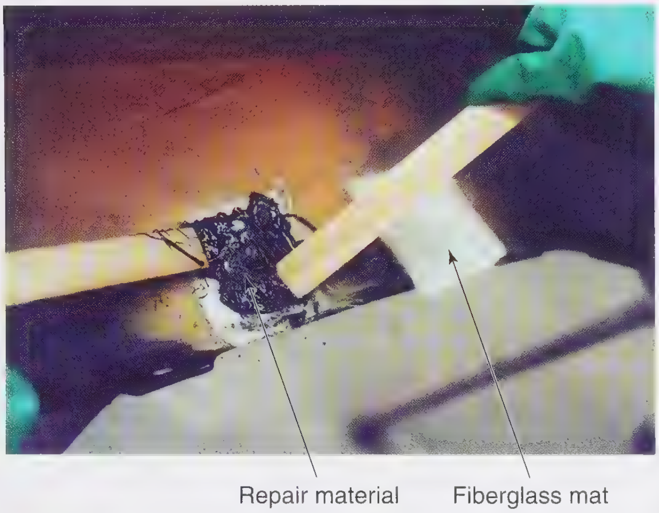


Figure 11-26. *The fiberglass mat is held in place while a spreader is used to spread the repair material.*

The V-groove is made with a die grinder and bit. The back side of the damage is V-grooved first. The plastic is cut halfway through its thickness. **Figure 11-27** shows this procedure. Once repairs are completed on the back side, the front side is V-grooved. The front V-groove should cut through half the thickness of the plastic and meet the melted rod from the back side of the repair. After V-grooving, the edge of the panel should be sanded with coarse sandpaper.

Beveling

To ensure that the repair material can be sanded smooth at the edge of the repair, the repair area must be beveled. See **Figure 11-28**. ***Beveling*** produces a gradual slope. Beveling can be done using a dual-action sander with 80-grit sandpaper. **Figure 11-29** shows a technician beveling the repair area. The bevel should extend out at least one inch in all directions from the edges of the damage.

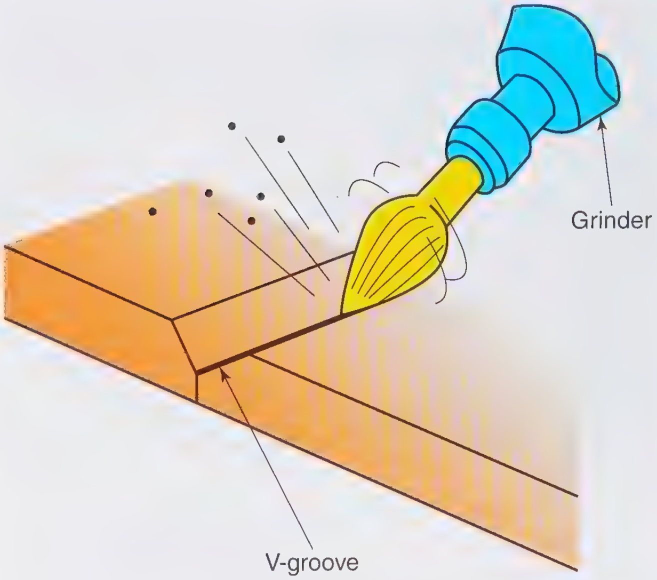


Figure 11-27. *A grinder and bit are used to cut a V-groove halfway through the material's thickness. (Urethane Supply Company)*

Binding

Binding is performed with an airless plastic welder. In ***binding***, only the filler rod is melted; the base plastic is not heated. This method is used to repair urethane parts with urethane rod. See **Figure 11-30**.

The shoe of the welder does not contact the surface of the urethane. The rod is melted in the feed shoe and is deposited in a V-groove. The softened rod is pressed into the V-groove. Then the shoe is pressed on the repair to complete the melting.

Apply melted rod to about 2" of the V-groove. Before the melted rod cools, go back and smooth it with the shoe. Continue this process, repairing 2" at a time until the V-groove is filled. The rod should be melted on both the back and front sides of the repair.

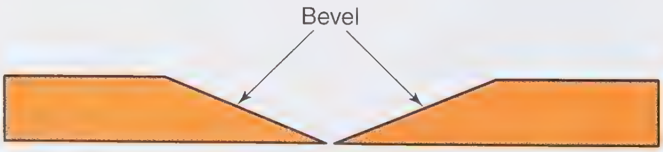


Figure 11-28. *Beveling is a gradual change in height.*

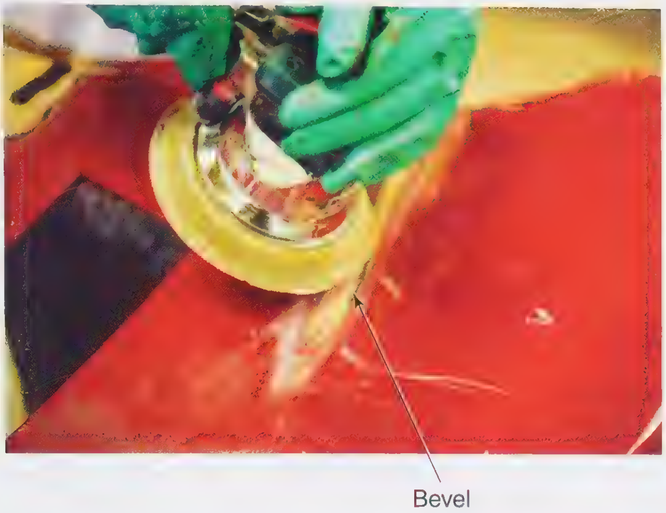


Figure 11-29. *Beveling can be done with 80-grit sandpaper on a DA sander.*

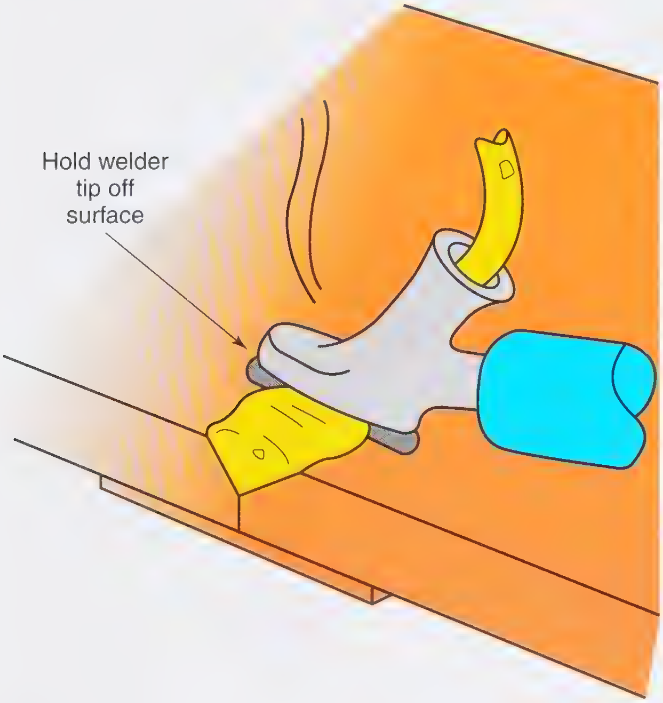

Hold welder tip off surface

Figure 11-30. *In binding, the urethane filler is melted but the urethane part is not heated. (Urethane Supply Company)*

Welding

Plastic welding can be used to repair thermoplastics. In ***plastic welding***, both the filler rod and the base material are melted.

The biggest problem in plastic welding is filler rod adhesion. This is because the ingredients used during the manufacture of a plastic can vary. For example, two parts that are both identified as TPO may have slightly different chemical compositions. A slight difference in the chemical composition between the filler rod and the damaged part may lead to adhesion problems. If necessary, test welds can be made on the back side of the part to determine what type of filler rod will adhere.

One way to avoid adhesion problems is to use slivers of the damaged part in place of filler rod. Weldable plastic can always be welded to itself. Find an inconspicuous area of the part to shave some material from. Melt the shavings, or slivers, and use them as filler rod.

Airless plastic welding uses either a feed shoe or a flat shoe. The feed shoe melts the plastic part and the welding rod at the same time. With the feed shoe placed in the V-groove, the welding rod is pushed through the hole in the shoe. The melted rod emerges from the hole in the bottom of the shoe to mix with the melted plastic of the part. Match the heat setting of the welder to the melt temperature of the rod. **Figure 11-31** shows welding with the feed shoe attached to the welder. The welding rod should not change color as it is melted in the shoe. Heat the plastic part by pressing the shoe along the V-groove, while depositing the melted rod. Apply melted rod to about two inches of the V-groove. Then go back before the melted rod cools and press on the weld with the edge of the shoe. This will mix the plastic and the melted rod. Smooth out the weld with the flat part of the shoe. Once one side of the part is welded, turn the part over and V-groove the other side. Weld the back side

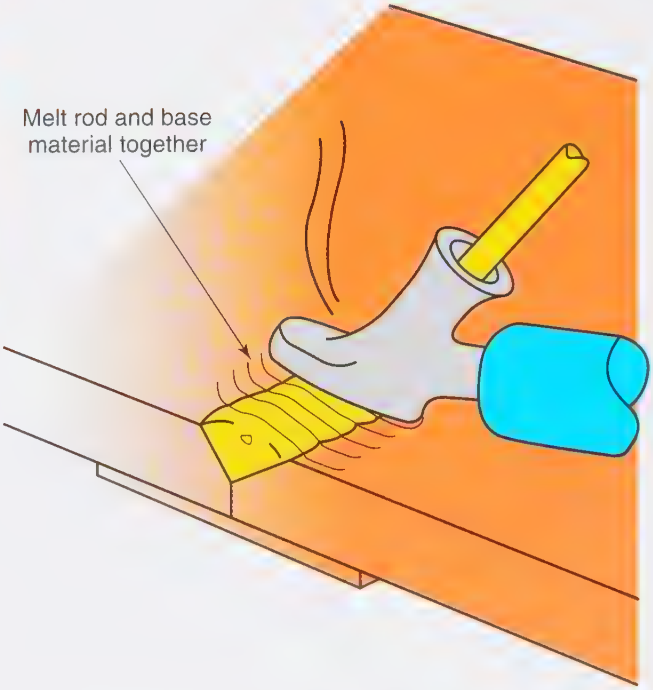

Melt rod and base material together

Figure 11-31. *In plastic welding, the plastic part and filler rod are melted together. (Urethane Supply Company)*

of the repair in 2" increments. This procedure is called two-sided welding.

Some plastic repair requires metal screen as reinforcement. In this type of repair, the screen is heated with the welder's flat shoe. The welder heat setting is adjusted for the type of plastic being repaired, usually PP, TEO or TPO. The metal screen is cut so that it extends at least 1" on either side of the break. The plastic where the screen will be melted is sanded with 80-grit sandpaper. The heated shoe is placed on the metal screen. The heated screen will melt into the plastic. The heating is continued until the screen is covered with melted plastic. Then the flat shoe is moved to an adjacent location to heat and melt the area.

Another type of weld that can be made with an airless plastic welder is a stitch tamp weld. A stitch tamp weld is used on ABS plastic only. No V-groove or welding rod is required in stitch tamp welding, although ABS can be welded using the conventional V-groove and welding rod method. In stitch tamp welding, the side of the feed shoe is pressed into the plastic, perpendicular to the break in the plastic. The shoe should be held in place until half the thickness of the plastic is melted. The feed shoe is moved about 1/4", and the process is repeated. When completed along the entire length of the break, the melts will resemble stitches. The roughness of these melts can be removed by heating them with the shoe to melt the ABS plastic back together. This is the tamp part of stitch tamp welding.

Hot-air welding is sometimes called speed welding, because it is faster than airless plastic welding. The hot-air welder must be hooked up to compressed air or a nitrogen gas tank. The welder has a setting for heat and another for discharge air pressure. Set the welder at the minimum values that will accomplish the job. For example with the heat set at medium, 3 psi discharge air pressure, and the air discharge tip about 1/4"–1/2" away from the plastic to be welded, the plastic should turn shiny and soften in about 2 seconds. If the plastic immediately bubbles, the heat setting or discharge air pressure is too high. Adjust one or both downward. If the plastic does not soften within 3 seconds, the heat or discharge air pressure is too low. Adjust one or both upward.

The broken plastic is V-grooved to create a large fusion area. There are four components to a good weld:

Temperature—The temperature that the filler rod and plastic part V-groove are heated to.

Angle—The angle of the discharge tip in relation to the filler rod and V-groove.

Pressure—The force used to push the filler rod into the V-groove.

Speed—The rate at which the discharge tip and filler rod are moved.

The filler rod is held at a 45° angle with the end of the rod in the V-groove while the discharge tip is positioned about 1/2" from the plastic and the filler rod at an angle that will direct about 70% of the heat at the part and 30% of the heat at the filler rod.

The part is thicker than the filler rod, so more heat is required to soften it. The key is to soften the rod and the surface of the V-groove at the same time and rate while pushing the softened rod into the V-groove. Too much heat will cause the plastic part to melt. Insufficient heat will not fuse the filler and the plastic part, leading to a weak weld. **Figure 11-32** shows a hot-air welding sequence. The rod should not melt so much that it changes shape. A welding speed of 6"–8" per minute is optimal.

NOTE

More than one pass with the welder may be required to fill the V-groove.

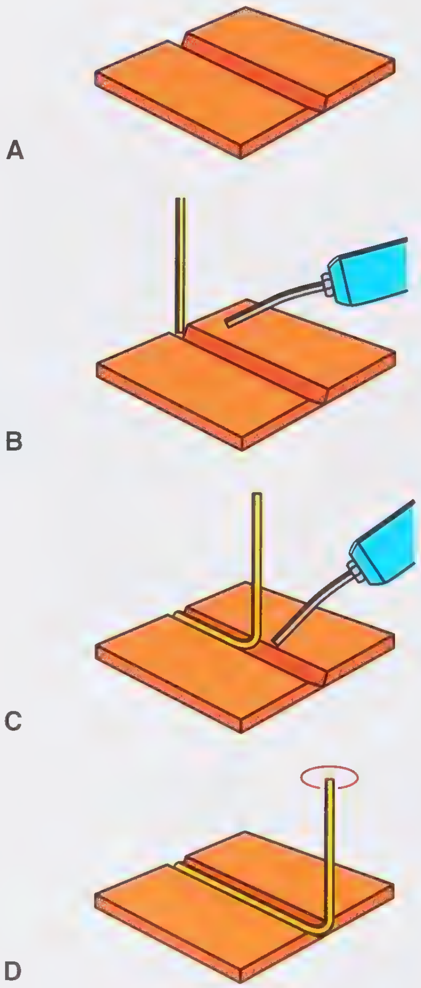


Figure 11-32. *The sequence for hot-air welding. A—Make a V-groove. B—Heat the plastic and the welding rod. C—Press the softened rod into the softened V-groove. D—When the end of the weld is reached, remove the welder, allow the rod to cool, and twist the rod to break off the end of the weld. (Urethane Supply Company)*

Bonding

Bonding involves using repair material either as a filler or as an adhesive to hold two pieces together. If the plastic being bonded contains olefin, an adhesion promoter must be applied before the repair material. The bonding process requires that the edges of the damage be beveled to allow an invisible featheredge. The mixed repair material is then applied to the repair area.

Fabricating

Fabricating is the process of making a part. When a portion of a plastic part is torn off and lost, that portion, if it is simple in design, can be fabricated. **Figure 11-33** shows fabrication of a bolt hole in a urethane bumper. The torn edge of the bumper is beveled. Aluminum body tape is placed on the outside of the bumper, bridging the hole. Urethane rod is melted onto the aluminum tape and beveled edge, and the repair is smoothed. When the area cools, the hole is drilled and the tape is removed. This procedure will also work on olefin-containing bumpers using universal rod.

Occasionally, a portion of a damaged part will be lost during a collision. If the part is flat and SMC, the missing portion can be fabricated and used in the repair of the damaged part. To fabricate a flat sheet of SMC, first cut out three pieces of fiberglass mat that are large enough for the required overlap. Lay down a sheet of waxed paper or plastic wrap on a solid surface, such as a workbench. Plastic sheets used to bag mask a vehicle can also be used. Mix and apply rigid repair material to the plastic wrap. Place one piece of fiberglass mat on the material. Place another piece of plastic wrap on top of the fiberglass mat. Use a saturation roller on the plastic wrap to mix the mat and the repair material. See **Figure 11-34**. The plastic wrap keeps the roller clean.

After rolling, take off the plastic wrap. Apply more repair material and another piece of mat, cover the mat with plastic wrap, and again roll these items together. Repeat this process one more time. Then remove the plastic, add one more layer of repair material, replace the plastic, and smooth the fabricated panel with the roller. When the fabricated panel hardens, use a cutoff wheel to cut it to the required size.

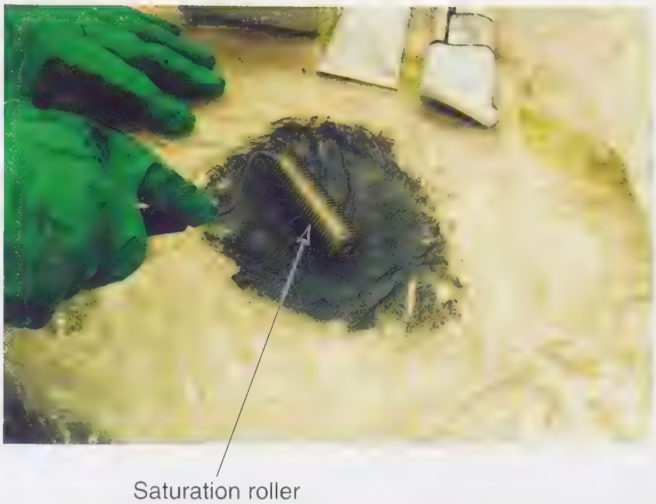


Figure 11-34. *The plastic sheet is on top of the rigid repair material and fiberglass mat. The saturation roller distributes the material into the mat.*

Finishing

Finishing is the last step in plastic repair. Finishing repairs the contour of panels, removes the roughness from weld areas, and restores texture.

Featheredging scratches or low areas is essential in any plastic repair. Featheredging, filling, and block sanding will make an invisible repair. Featheredge scratches in rigid plastic with 80-grit sandpaper on a sanding block. Gouges or deep scratches in rigid plastics, such as SMC, can be filled with rigid repair material or body filler. Check the instructions on the body filler can to see if it will adhere to SMC. If the back side of a break in rigid plastic is repaired with adhesives, the front side of the break can be featheredged and filled in the same way as a scratch.

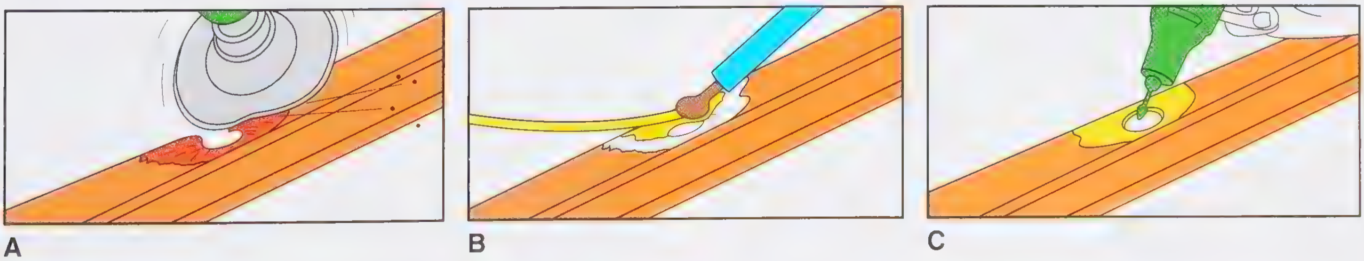


Figure 11-33. *Repairing a broken bolt hole. A—The broken edge is beveled and then a piece of aluminum tape is placed across the broken area. B—Welding rod is melted onto the tape and beveled area. C—Hole is shaped with a grinder bit. (Urethane Supply Company)*

In semi-rigid and flexible plastics, gouges, low areas, or the front side of a tear repaired with adhesives can be filled with adhesive. Featheredging is important here too. If the plastic contains olefin, an adhesion promoter is required before application of any repair material. Bevel the scratch or break with 80-grit sandpaper on a block. With either rigid or flexible repair material, apply an overfill of repair material, allow the material to cure thoroughly, and then sand with 80-grit, 180-grit and 320-grit sandpapers. Sand the material to an exact match of the original contour.

The roughness resulting from plastic welding can be sanded with progressively finer grits of sandpaper. Start with 80-grit sandpaper. Once the weld area is level, switch to 180-grit sandpaper. When the 80-grit sand scratches are removed by 180-grit sandpaper, switch to 320-grit sandpaper. Power sanding with a DA sander is acceptable on all plastics except those containing olefin. Olefin-containing plastics melt with heat, and the heat produced by power sanding will cause olefin plastic to melt and clog the sandpaper. Use hand sanding on olefin plastic. If gouges are found in the plastic after sanding, fill the gouges or low areas as explained previously.

Texturing

Repair will leave a smooth area on textured plastic. To restore texture, a special ***texturing paint*** is used. One type of texturing paint is applied with a spray gun. Another type of texturing paint is supplied in a spray can. The texturing paint is thin. It is meant to be gradually built up in layers.

When restoring texture to a plastic surface, a test panel, **Figure 11-35**, should be sprayed first. The texture can be modified by gun speed, air pressure, gun distance, and the number of coats. Hold the spray gun about 18"–24" away from the surface. Spray the test panel to decide on what combination of gun speed, air pressure, gun distance, and number of coats will best match the original texture. Lowering air pressure, decreasing gun speed, decreasing distance, and increasing the number of coats increases the grain size.

Allow flash time between coats. Never put the texture paint on wet because it will not have a grain pattern if it flows out. Once the proper grain pattern has been established, spray the repair area. It may take ten or more coats to achieve the proper grain pattern. When the textured paint has dried, lightly scuff the paint and the surrounding texture with a scuff pad as shown in **Figure 11-36**. This will help blend in the repair. The part can be painted as the next step.

Another type of texturing paint is applied with a spray can. The only variation in texture possible is to hold the spray can closer to or farther away from the surface. When spraying from farther away, the paint will go on dryer, causing rougher texture. When using a spray can to retexture a bumper, it may be easier to sand down the texture and spray the entire area with texturing paint.

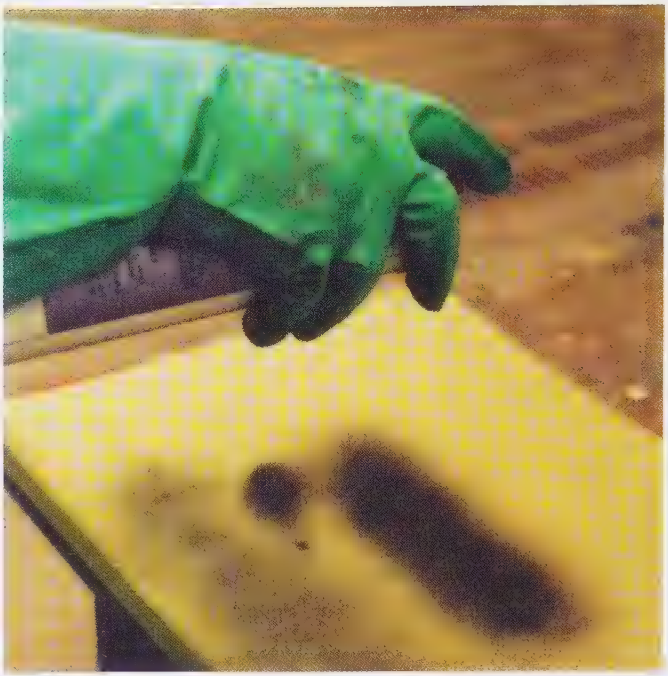


Figure 11-35. *This texturing paint is sprayed from a can. A test panel is sprayed first to find the proper application to match the texture.*

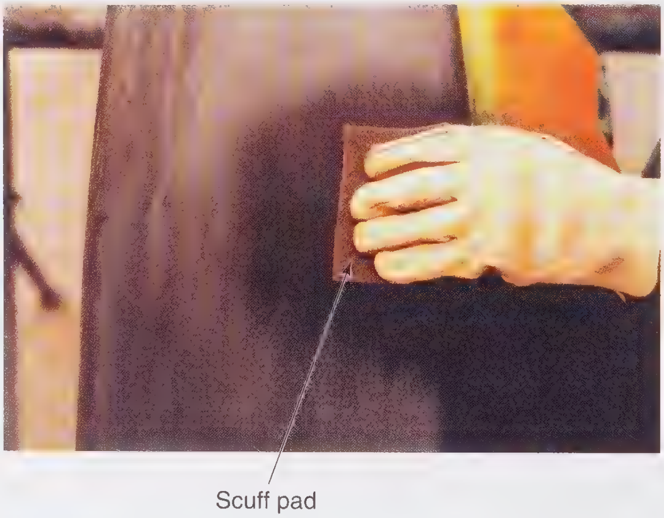


Figure 11-36. *A scuff pad is used to even out the paint texture.*

Repairing Specific Types of Damage

The following sections outline the repair of common types of damage on various automotive plastics. If the same type of repair can be used on several different plastics, all the plastic types will be listed.

Flexible or Semi-Rigid Non-Olefin Plastic Gouge (RIM, RRIM, Xenoy, GTX, Pulse, Urethane)

Parts made from flexible or semi-rigid non-olefin plastics (RIM, RRIM, Xenoy, GTX, Pulse or Urethane) include bumper covers, fenders, door skins, and ground effects. Contact with a sharp object can dig a gouge in these parts. For example, a vehicle can be driven too close to a brick wall so the bumper cover scrapes the bricks. The bricks will dig gouges in the plastic. The bumper cover shown in **Figure 11-37** is not broken, but the surface has gouges. The procedure for this type of repair is as follows:

1. Read the estimate.
2. Remove the part from the vehicle—This is not required for repair because access to the back side is not required. However, repainting may require removal.
3. Clean—Wash the plastic with soap and water followed with plastic cleaner.
4. Identify the plastic.
5. Plan the repair
6. Repair the damage—Bevel the edge of the gouge or gouges with 80-grit sandpaper. Remove all the paint from the fill area with 180-grit sandpaper. Featheredge the broken paint edge with 320-grit sandpaper. Mix and apply flexible adhesive material to overfill the beveled gouges. Some flexible adhesive manufacturers recommend that the filler be applied to fill the gouge and cover the featheredged paint. This is so that the adhesive bites into the paint and is less likely to roll off and fail while sanding a featheredge in the adhesive. Allow the adhesive to cure. Finally, sand the cured adhesive with 80-, 180-, and 320-grit sandpaper. Use the undamaged contour as a guide for sanding.

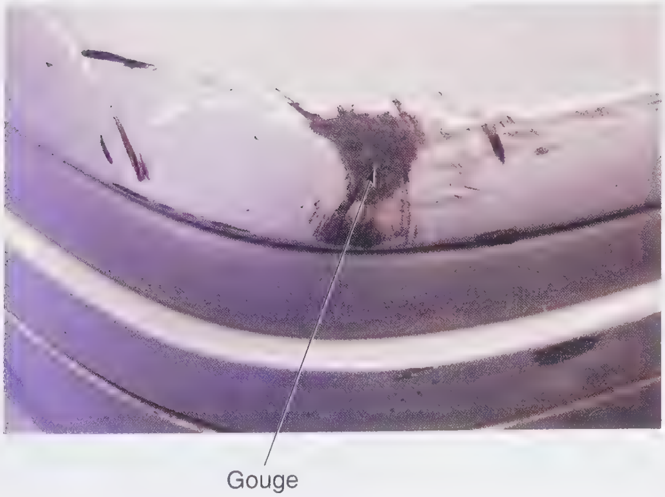


Figure 11-37. *The gouges in this Xenoy bumper can be repaired with adhesive filler.*

Flexible or Semi-Rigid Tear—Binding Repair (Urethane, RIM, RRIM, Xenoy, GTX, Pulse, TPO, TEO, PP)

A bumper cover or ground effect, fender or door skin can be torn by a collision with a sharp object. The tear is a break in the plastic. All of the types of plastic listed can be repaired by binding with universal rod. Binding involves melting the repair material but not the plastic part during the repair. Binding with urethane rod can also repair urethane plastic. The procedure for this type of repair is as follows:

1. Read estimate.
2. Remove part from vehicle.
3. Clean—Wash the outside of the part with soap and water, and clean it with plastic cleaner. Clean the repair area on the back side of the part with soap and water and plastic cleaner.
4. Identify the plastic.
5. Plan the repair.
6. Align—If stretching is present, heat and reshape the plastic. Hold the edges of the tear together and on the front side apply aluminum tape over the tear. This will align the tear for binding.
7. Repair—To repair urethane plastic with urethane rod, use a die grinder to cut a V-groove along the back side of the tear halfway through the plastic. Sand the edge of the V-groove to a featheredge with 80-grit sandpaper. Install the feed shoe on the airless plastic welder and set the heat knob to preheat. When the welder has warmed up, set heat knob to urethane. Do not touch the plastic part with the feed shoe. Push the urethane rod through the hole in the feed shoe. The urethane rod should melt when it is pushed through the shoe but not burn. Burned urethane is bubbly and dark colored; melted urethane is soft and clear. Melt the urethane into the first two inches of the V-groove. Allow the urethane rod to cool and then go back and smooth out the rod with the shoe. Touch the shoe to the rod only, not the surrounding plastic. Continue this process until the entire V-groove is filled. Turn the part over and remove the alignment tape. Repeat the process on the front side: V-groove halfway through, sand a featheredge with 80-grit sandpaper, melt urethane rod, smooth urethane rod.

To use a universal rod to repair the tear in the TPO bumper cover shown in **Figure 11-38**, cut a V-groove in the back side of the break. Use a DA sander with 40-grit sandpaper to make a 1 1/2" bevel in the plastic. Sand a featheredge into the surrounding paint with 80-grit sandpaper. Install the flat shoe on the welder and set the welder to preheat. When the welder has warmed up, set the welder to the highest heat setting. Touch the universal rod to the flat tip to melt the rod.

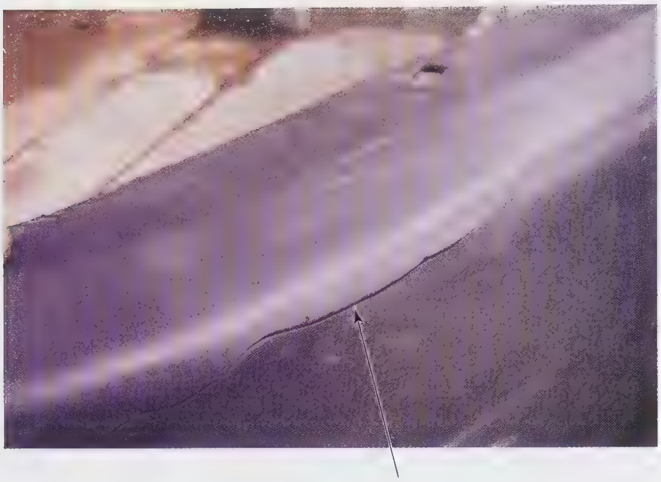


Figure 11-38. *Notice the texture on this bumper cover. Binding will repair the tear in this olefin-containing bumper cover.*

Turn the rod over and place the melted portion on the bevel. This will allow the melted portion to adhere to the plastic. Use the edge of the flat shoe to cut the universal rod that is attached to the plastic. Continue this process of melting, adhering, and cutting until the beveled area is filled. Use the flat shoe to smooth out the universal rod in the bevel. Turn the part over, remove the alignment tape and repeat the process on the front of the tear.

Sand the filled area to the proper contour with 80-grit sandpaper followed with 180-grit sandpaper. If urethane rod was used for the repair, it will not featheredge very well. The edges will not adhere and will roll off when being sanded. Cover the featheredge areas with flexible adhesive, allow the adhesive to cure, and sand again. The universal rod has better adhesion than urethane rod and should give a better featheredge than the urethane rod. However, if the universal rod will not featheredge, it can be covered with flexible adhesives also. Apply adhesion promoter to olefin-containing plastic before using any adhesive.

Flexible or Semi-Rigid Non-Olefin Plastic Tear—Adhesive Repair (RIM, RRIM, Xenoy, GTX, Pulse, Urethane)

Adhesives can be used to repair a tear in flexible or semi-rigid non-olefin plastics. Contact with a sharp object can cause a tear in a bumper cover, ground effect, fender, or door skin. An impact on a Xenoy bumper can break the slide mount from the bumper. The slide mount is a boxed-in area on the bumper that slides on to a mounting stud on the fender. If the slide mount is not damaged but is separated from the bumper, it can be reinstalled with adhesive.

The procedure for this type of repair is as follows:

1. Read the estimate.
2. Remove the part from the vehicle.
3. Clean—Wash the outside of the part with soap and water followed with plastic cleaner. On the inside of the part, clean the repair area with soap and water and plastic cleaner.
4. Identify the plastic.
5. Plan the repair.
6. Align —If stretching is present, heat and reshape the plastic. Hold the edges of the tear together and apply aluminum tape to the front side of the tear. This will hold the tear together while the back side is repaired.
7. Repair—On the back side of the part, sand 1" on either side of the break and 1" beyond each end of the break with 80-grit sandpaper. Prepare a reinforcement. Fiberglass matt or cloth may be used as a reinforcement. If a backer is used instead of fiberglass reinforcement, it should be a similarly shaped piece of the same type of plastic. The reinforcement or backer should be 2" wide and 2" longer than the tear. Mix and apply flexible adhesive to the sanded area on the back side of the break. Apply the backer or reinforcement. Apply additional adhesive over the reinforcement. Then apply another layer of reinforcement and adhesive on top of that. A backer does not need an application of additional adhesive. Allow the adhesive to cure. Turn the part over and remove the alignment tape. Bevel the tear with 80-grit sandpaper on a DA sander. Featheredge the adjacent paint with 180- and 320-grit sandpaper. Mix and apply flexible adhesive to the featheredged area. Some adhesive manufacturers recommend that the adhesive be applied to the paint along the featheredge. This allows the adhesive to bind with the paint, producing a stronger bond for sanding. To reinstall a broken slide mount, apply adhesive to the slide mount and place it in the correct location on the bumper. Sand the cured adhesive to the proper contour with 80-, 180- and 320-grit sandpaper.

CAUTION

On Xenoy bumpers, do not attempt to repair tears or breaks within the reinforced (boxed-in) area of the bumper. Figure 11-39 shows the reinforced area in which repairs should not be made.

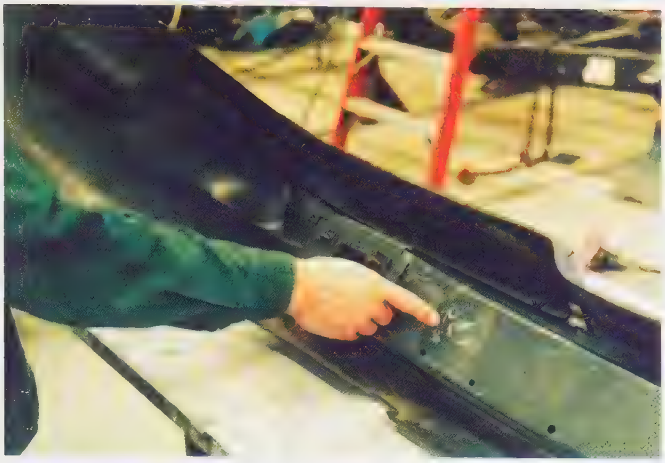


Figure 11-39. *Do not repair a Xenoy bumper if the damage is in the reinforcement. The technician is pointing to the reinforcement.*

Olefin Gouge (TPO, TEO)

Olefin-containing bumper covers are quite common. Gouges can be made in olefin plastics by contact with an abrasive surface. A gouged bumper cover is shown in **Figure 11-40**. To repair gouged olefin-containing plastic:

1. Read the estimate.
2. Remove the part from the vehicle.
3. Clean—Wash the part with soap and water, and clean it with plastic cleaner.
4. Identify the plastic—Olefin-containing plastics feel slick or greasy, and melt when sanded with a high-speed sander.
5. Plan the repair.
6. Repair—Bevel the gouge or gouges with 80-grit sandpaper. Use hand sanding because sanding with a DA may cause the plastic to melt. Featheredge the surrounding paint with 180-grit sandpaper, followed with 320-grit sandpaper. Apply adhesion promoter to all the bare plastic. Allow the adhesion promoter to dry. Mix and apply flexible adhesive to the featheredged area. Some adhesive manufacturers recommend that adhesive be applied over the featheredged paint for better adhesion. Allow the adhesive to cure. Then sand the cured adhesive to proper contour with 80-, 180- and 320-grit sandpaper. If any low spots are found, adhesion promoter must be applied again if adhesives will be applied to bare olefin plastic.

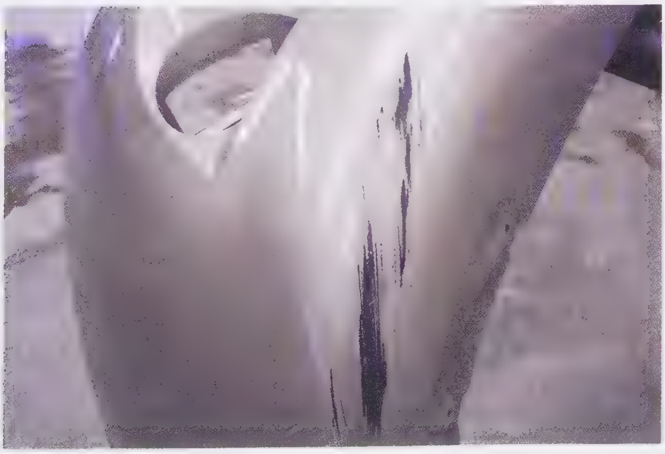


Figure 11-40. *The gouges in this olefin-containing bumper cover can be filled with adhesives.*

Olefin Tear—Bonding Repair (TPO, TEO)

Olefin-containing plastics, such as bumper covers, can be torn by a collision by a sharp object or by an impact that rips the bumper cover from the mounts. **Figure 11-41** shows a torn olefin-containing bumper cover. To repair torn olefin-containing plastic:

1. Read the estimate.
2. Remove the part from the vehicle.
3. Clean—Wash the front side of the part with soap and water, and clean it with plastic cleaner. On the back side, just wash and clean the repair area.
4. Identify the plastic.
5. Plan the repair.
6. Alignment—If stretching is present, use heat to reshape the plastic. Hold the edges of the tear together and apply aluminum tape to the front side of the tear. This will hold the tear together while the back side is repaired.

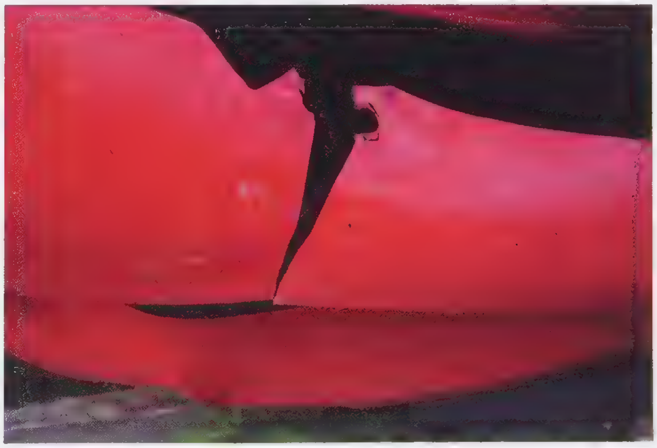


Figure 11-41. *Alignment tape will hold the edges of the tear together while adhesives and a reinforcement or backer are applied to the back side.*

7. Repair—On the back side of the part, sand 1" on either side of the tear and 1" beyond each end of the tear by hand with 80-grit sandpaper. Apply adhesion promoter to the sanded area and allow the adhesion promoter to dry. Prepare the reinforcement or backer. The reinforcement or backer should be 2" wide and 2" longer than the tear. Mix and apply flexible adhesive to the sanded area. Install the reinforcement or backer. If reinforcement is used, apply additional adhesive over the first layer of reinforcement, apply another layer of reinforcement, and then apply adhesive on top of that. When the adhesive has cured, remove the alignment tape from the front side. Sand a featheredge in the tear with 80-, 180-, and 320-grit sandpaper. Apply adhesion promoter to the bare plastic. Mix and apply flexible adhesive to the featheredged area after the adhesion promoter has cured. Sand the cured adhesive to proper contour with 80-, 180-, and 320-grit sandpaper. If any low spots are found, adhesion promoter must be applied again if adhesives will be applied to bare olefin plastic.

Thermoplastic Break (Xenoy, ABS, TPO, TEO, PP, PE)

Bumper covers can be made from Xenoy, TPO, or TEO. A collision can cause a break or tear in these bumper covers. Often, when a bumper cover moves during a collision, the mounting flange of the bumper cover, which is bolted to the fender, does not move and is torn from the bumper cover. The slide mounts on Xenoy bumpers can be broken from the bumper.

ABS plastic, shown in **Figure 11-42**, is used to make grilles and some interior parts. ABS parts can crack from an impact, especially their mounting tabs. Parts commonly made from PP, such as fan shrouds and fender liners, can also be broken in a collision.

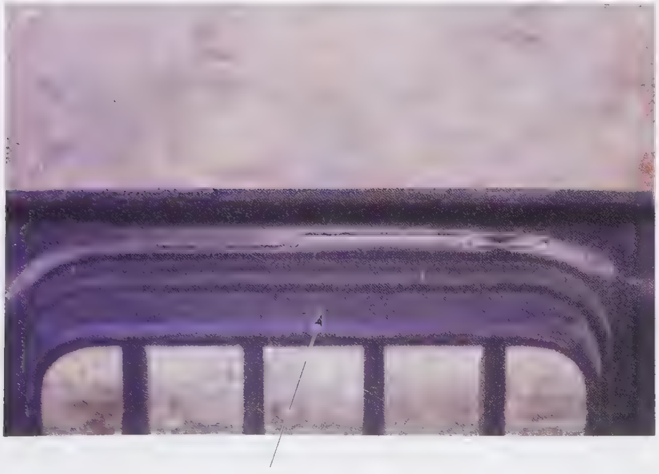


Figure 11-42. *The break in this ABS plastic grille can be repaired by welding.*

To repair a thermoplastic break:

1. Read the estimate.
2. Remove the part from the vehicle.
3. Clean—Wash the front side of the part with soap and water, and clean it with plastic cleaner. On the back side just wash and clean the repair area. On a fan shroud and a fender liner, just wash both sides of the repair area. These parts will not be painted.
4. Identify the plastic.
5. Plan the repair.
6. Alignment—If stretching is present, use heat to reshape the plastic. Hold the edges of the break together and apply aluminum tape to the front side of the break. This will hold the break together while the back side is welded.
7. Repair—For Xenoy, TPO, TEO, and PP, sand the back side of the break 1" around all the sides with 80-grit sandpaper. Cut out aluminum screen to fit in the sanded area. Use the flat shoe of airless plastic welder to melt the screen into the plastic. Hold the flat shoe in one place until the plastic melts and the screen sinks into the melted plastic. Move to an adjacent area and melt the screen into the plastic in the same way. Continue heating and melting until the entire screen is melted into the plastic. Remove the alignment tape, cut a V-groove into the break, and make a featheredge into the paint with 180- and 320-grit sandpaper. Use the feed shoe to melt the appropriate welding rod into the plastic. If welding rod will not adhere to the plastic, shave off slivers of the part from a hidden area. Melt these slivers in the feed shoe to fill the featheredged area. On fan shrouds, melt another section of screen into the front side of the shroud. These parts are not often seen and appearance is not critical.

ABS grilles are often coated with chrome finish. The chrome finish cannot be repaired, but the underlying plastic can be. With careful alignment, the break in the chrome finish may not be obvious once the plastic is repaired. Use the stitch tamp method to weld the back side of the ABS part. Use the edge of the feed shoe to melt grooves perpendicular to the break. Grooves should melt about halfway through the plastic and be placed every 1/4". When grooves are completed, go back and melt the rough grooves together. To weld a Xenoy slide mount, melt a 1" wide section of screen to the slide mount and the bumper. The screen should be long enough to be welded along the entire length of the slide mount. Weld the top, bottom, and boxed end.

Appearance parts will be seen by the customer; nonappearance parts will not. Do not finish sand polypropylene parts, such as fan shrouds and fender liners. An engine part is not usually an appearance part. On bumper covers and other appearance parts, finish sand the welded plastic with 80-, 180-, and 320-grit sandpaper.

Gouges or gaps remaining after sanding can be filled with adhesives. Apply adhesion promoter if required.

SMC or FRP Scratch

Rigid parts, such as SMC and FRP header panels, hoods, doors, rear hatches, and running boards, can be damaged by scraping the part against a rough surface or by vandalism. Scratch damage does not break the part. **Figure 11-43** shows a scratch in SMC. To repair a scratch in SMC:

1. Read the estimate.
2. Remove the part from the vehicle—Because only the front side of the panel will be worked, the part can be left on the vehicle unless painting requires that the part be removed.
3. Clean—Wash the front side of the part with soap and water, and clean it with plastic cleaner.
4. Identify the plastic.
5. Plan the repair.
6. Repair—Use a DA sander and 80-grit sandpaper to featheredge the scratch. The featheredge should be at least 1" wide. Complete the featheredge with 180- and 320-grit sandpaper by sanding into the paint. Mix body filler or rigid adhesive and apply an overfill to the featheredged area. Most body filler will adhere to SMC and FRP. Allow the filler to cure. Then sand the cured filler to the proper contour with 80- and 180-grit sandpaper.

SMC Break

NOTE

Parts with boxed sections, such as rear hatches and front hoods, may not be repairable because this method requires access to the back side of the part.

Rigid parts, such as a hood, rear hatch, header panel, or door, can be cracked and broken in a collision, **Figure 11-44**. Always check the part for internal cracks. In most cases inaccessible internal damage will require that the part be replaced rather than repaired. The steps for repairing rigid SMC parts include:

1. Read the estimate.
2. Remove the part from the vehicle—A hatch or hood may not need to be removed because opening the door, hatch, or hood will provide access to the back side of the part. However, interior trim on a door or hatch must be removed for access to the inside of the part.
3. Clean—Wash the front side of the part with soap and water, and wipe it down with plastic cleaner. Wash and clean the inside of the part in the area of the break.
4. Identify the plastic.
5. Plan the repair.
6. Alignment—If unbroken fibers prevent alignment, use a hacksaw blade to cut the fibers so the part can be properly positioned. Aluminum tape may not be strong enough to hold the broken front side of the SMC in place. You may need to use paint sticks and clamps instead.
7. Repair—Sand 2" on either side and at either end of the back of the break with 80-grit sandpaper. Cut out a backer to fit the sanded area. The backer should have the same contour as the damaged area. Also sand the backer with 80-grit sandpaper. Mix and apply body filler or rigid adhesive to glue the backer in place. When the filler or adhesive has cured, remove the alignment material and featheredge the front side of the break. Start with 40-grit sandpaper to make the featheredge. Sand all the way to the backer. Then complete the featheredge with 80-grit and finish with 180-grit in the surrounding paint. The featheredge should be at least 1 1/2" wide.

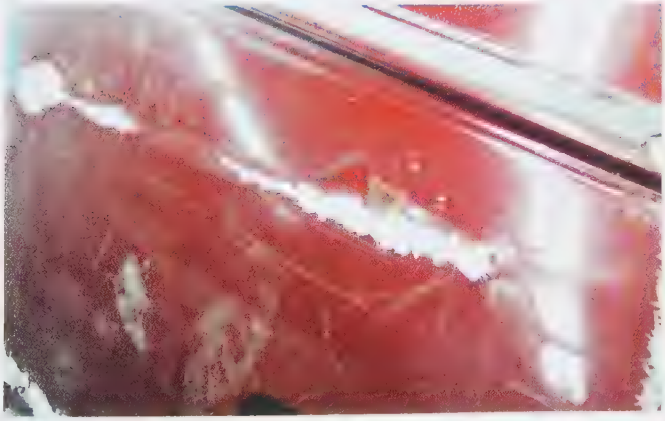


Figure 11-43. *Gouges and scratches in SMC can be repaired with body filler.*

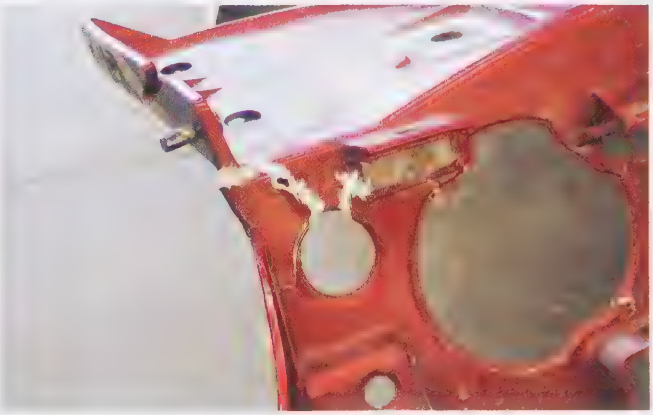


Figure 11-44. *Repair of cracked SMC requires adhesives or body filler and a backer.*

Cut out two pieces of fiberglass cloth or mat. Both pieces should be as long as the featheredge. One piece should be wide enough to fit into the bottom of the featheredge on top of the backer. The other piece should be the same width as the featheredge. Place the narrow piece of fiberglass mat or cloth into the featheredge. Mix body filler or rigid adhesive and apply it to the featheredge, covering the piece of fiberglass. Set the wide piece of fiberglass in place and cover it with filler or adhesive. Apply an overfill of filler or adhesive. Block sand the cured filler or adhesive to the proper contour with 80-grit and 180-grit sandpaper.

SMC Splice

The damage to an SMC part may be so great that the damaged area cannot be repaired. In this case, the damaged area can be cut out and replaced. This process is called splicing or sectioning. **Figure 11-45** shows a damaged SMC panel with a portion missing. This will require splicing during repair. If an SMC part must be replaced, the joint between the existing panel and the splice panel should be between mill-and-drill pads.

1. Read the estimate.
2. Remove the part from the vehicle—A door, hatch, or hood may not have to be removed because opening the component will provide access to the back of the part. However, interior trim on a door or hatch must be removed for access to the inside of the part.
3. Clean—Wash the front side of the part with soap and water, and wipe it down with plastic cleaner. Wash and clean the inside of the part in the area of the damage.
4. Identify the plastic.
5. Plan the repair.
6. Alignment—Alignment may not be possible due to the extent of the damage.
7. Repair—A patch panel may need to be fabricated.

In some cases, replacement parts are available. Use aluminum tape to hold the splice section in place while it cures. When the adhesive or filler has cured, use 40-grit sandpaper on a DA to sand a featheredge in the gaps between the original panel and the splice panel. Sand down to the backing strips. Complete the featheredge with 80-grit and then 180-grit sandpaper. Cut out strips of fiberglass cloth or mat. Make two strips for each gap. The strips should be the same length as the gap. One strip should be as wide as the base of the gap, and the other strip should be as wide as the top of the featheredge. Position the narrow strip in the gap. Mix and apply rigid adhesive or body filler to the gap. Insert the wide strip and cover it with rigid adhesive or body filler. Apply an overfill of rigid adhesive or body filler to the gaps. Allow the filler to cure. Then block sand the cured filler to proper contour with 80- and 180-grit sandpaper.

FRP Break

Aftermarket parts, such as van running boards, may be made of FRP. **Figure 11-46** shows a broken FRP part. To repair an FRP part:

1. Read the estimate.
2. Remove the part from the vehicle.
3. Clean the part—Wash the front side of the part with soap and water, and wipe it down with plastic cleaner. Wash and clean the inside of the part in the area of the break.
4. Identify the plastic.
5. Plan the repair.
6. Alignment—Use a hacksaw blade to cut unbroken fibers so the damaged area can be shifted into alignment. Hold the part in alignment with paint sticks and clamps on the front side.

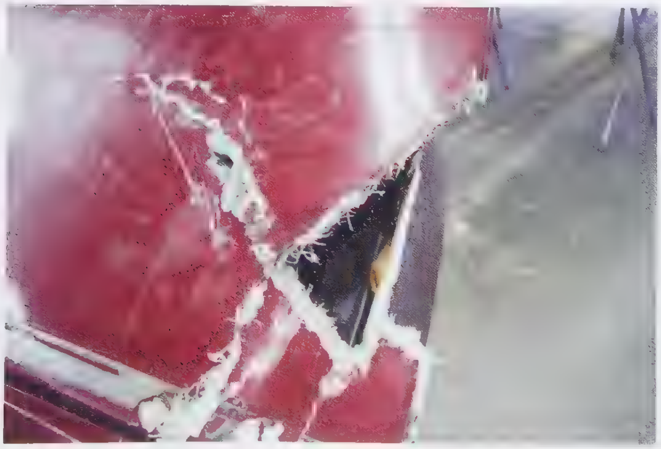


Figure 11-45. *A flat splice piece can be fabricated to repair this damaged SMC door.*

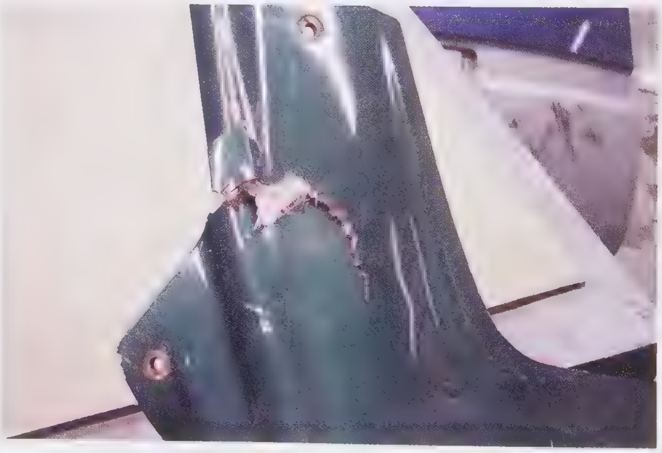


Figure 11-46. *This broken shroud will be repaired with fiberglass resin and fiberglass mat.*

7. Repair—Grind the back side of the part with 36-grit sanding disk. Bevel the plastic at least 2" on either side of the break. Grind nearly through the panel. Cut out 3 pieces of fiberglass mat the same length as the break. One piece should be 1" wide, another should be 2" wide, and the last should be 4" wide. Mix fiberglass resin and hardener. Put the 1" wide piece of fiberglass on a sheet of cellophane. Pour mixed fiberglass resin on the mat. Once the mat is saturated, place the mat in the featheredged area. Mix the resin and the 2" piece of fiberglass on the cellophane and place the 2" piece on top of the 1" piece in the featheredged area. Finally pour the resin on the 4" piece of mat on the cellophane, and apply the 4" piece to the featheredged area. If resin drips out of the front side of the break, tape cellophane over the break to contain the resin. Allow the resin to cure. Remove the alignment material and featheredge the front side of the break with 80-, 180-, and 320-grit sandpaper. Apply an overfill of body filler to the featheredged area. Block sand the cured body filler with 80-grit sandpaper, followed with 180-grit sandpaper.

Summary

- A rigid plastic will not bend or flex without breaking.
- A semi-rigid plastic will bend somewhat without breaking.
- A flexible plastic can be bent 180° without breaking.
- Thermoplastics can be welded with special plastic welding equipment.
- Thermoset plastics burn rather than melt when heated.
- The die grinder is used to cut a V-groove in the plastic part being repaired.
- An airless plastic welder has an adjustable heat setting so it can be used to melt various types of plastic filler rods.
- Hot air from a hot-air welder's discharge tip heats the filler rod and the plastic part at the same time, fusing them together.
- Adhesives are two-part repair materials. When mixed together, the two parts undergo a chemical change and cure, or harden.
- Adhesion promoter changes the chemistry of the olefin plastic surface, allowing adhesives to stick.
- Mesh is used as reinforcement when making plastic repairs.
- Many plastic repairs require access to both sides of the part.
- For proper adhesion, both sides of the plastic part must be clean before attempting repairs.
- A backer is a piece of plastic that is the same type of material as the damaged part.
- A V-groove increases the contact surface area of the adhesive or weld repair and also makes a featheredge that will hide the repair.
- To ensure that the repair material can be sanded smooth at the edge of the repair, the repair area must be beveled.
- During plastic welding, both the filler rod and the base material are melted.
- There are four components to a good weld: temperature, angle, pressure, and speed.
- Bonding involves using repair material either as a filler or as an adhesive to hold two pieces together.
- Fabricating is the process of making a part.
- Finishing repairs the contour of panels, removes the roughness from weld areas, and restores texture.

Review Questions

Please do not write in this textbook. Place your answers on a separate sheet of paper.

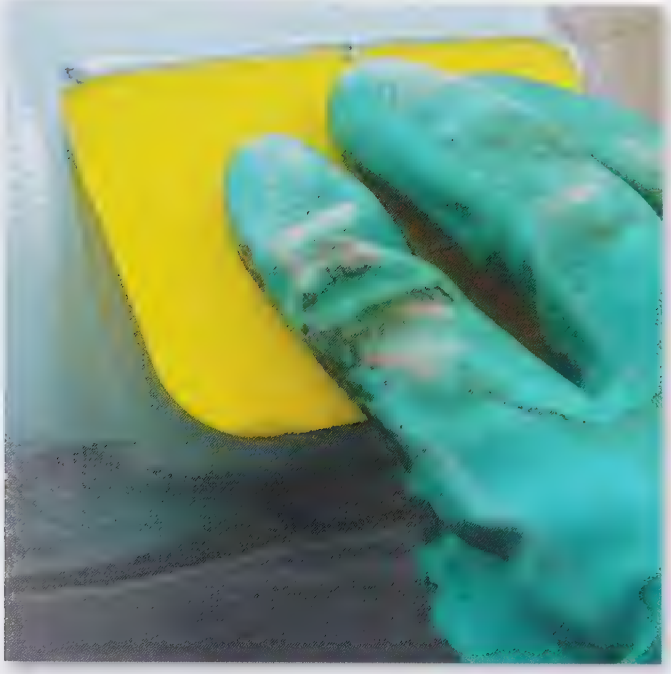
1. What is a polymer?
2. Thermoplastics cannot be welded. True or False?
3. The ISO symbol for the plastic polypropylene is ______.
4. Before adhesives are applied to an olefin-containing plastic, ______ should be put on the surface.
5. The two types of welder shoes are ______ and ______.
6. When using a mixing tube, how much of the material first released from the tube is discarded?
7. Plastic repair mesh can be made from metal or plastic. True or False?
8. The first step in plastic repair is cleaning the part with ______ and ______.
9. Plastic can absorb solvents. True or False?
10. Explain what happens when a high speed grinder is used on a plastic-containing olefin.
11. Name three methods used to identify an unknown plastic.
12. Bent plastic can be reshaped by heating with an oxyacetylene torch. True or False?
13. A bumper cover has a tear. There is a reinforcement directly behind the cover. What should be used as a reinforcement when repairing the tear?
14. What is the purpose of a V-groove?
15. A urethane repair in which only the filler rod is melted is called ______.
16. The texture of a plastic part is restored with ______.
17. List the steps in the bonding repair of a tear on a urethane bumper cover.
18. Aluminum body tape can be used to align torn edges on a plastic part. True or False?
19. If the slide mount on a Xenoy bumper is separated from the bumper, it can be reinstalled with ______.
20. List the steps in repairing an SMC scratch.

ASE-Type Questions

1. The cost of replacing a bumper cover is less than the cost of repair. Technician A wants to repair the cover. Technician B wants to replace the bumper. Who is right?
   (A) A only.
   (B) B only.
   (C) Both A and B.
   (D) Neither A nor B.
2. All of the following can cause a lack of adhesion EXCEPT:
   (A) a smooth surface.
   (B) a sanded surface.
   (C) surface chemistry.
   (D) surface cleanliness.
3. A plastic part is to be cleaned. Technician A wants to use soap and water. Technician B wants to use wax and grease remover. Who is right?
   (A) A only.
   (B) B only.
   (C) Both A and B.
   (D) Neither A nor B.
4. Which of the following can be melted and still retain design properties?
   (A) Thermoset plastic.
   (B) Thermoplastic.
   (C) SMC.
   (D) Fiberglass.
5. All of the following plastics can be welded EXCEPT:
   (A) ABS.
   (B) PP.
   (C) SMC.
   (D) TPO.
6. Technician A says that plastic adhesive is available as a hand mix. Technician B says that plastic adhesive is available as a tube mix. Who is right?
   (A) A only.
   (B) B only.
   (C) Both A and B.
   (D) Neither A nor B.
7. Before repairing a plastic part, the part should be cleaned with ______.
   (A) wax and grease remover
   (B) lacquer thinner
   (C) plastic cleaner
   (D) enamel reducer
8. A plastic bumper cover smears when ground. Technician A says the cover contains olefin. Technician B says the part does not contain olefin. Who is right?
   (A) A only.
   (B) B only.
   (C) Both A and B.
   (D) Neither A nor B.
9. All of the following can be used to identify plastic EXCEPT:
   (A) an ISO symbol.
   (B) the float test.
   (C) a test weld.
   (D) a VIN.
10. When binding, how much of the V-groove is filled at one time?
    (A) 1".
    (B) 2".
    (C) 3".
    (D) 4".
11. When using a feed shoe plastic welder, the filler rod changes color as it passes through the shoe. Technician A says that this occurrence is normal. Technician B says that the welder's heat setting is too high. Who is right?
    (A) A only.
    (B) B only.
    (C) Both A and B.
    (D) Neither A nor B.
12. An SMC part needs to be fabricated. Technician A says that fiberglass mat is needed. Technician B says that plastic wrap or waxed paper is needed. Who is right?
    (A) A only.
    (B) B only.
    (C) Both A and B.
    (D) Neither A nor B.
13. Body filler can be used to repair all of the following EXCEPT:
    (A) PP.
    (B) FRP.
    (C) SMC.
    (D) metal.
14. The grain in texturing paint can be controlled by ______.
    (A) paint gun air pressure
    (B) paint gun speed
    (C) number of coats
    (D) All of the above.
15. A gouge in a urethane bumper should be repaired by ______.
    (A) filling it with body filler
    (B) welding
    (C) filling it with adhesive
    (D) grinding
16. A tear in a urethane bumper cover is to be repaired. Technician A wants to weld it. Technician B wants to melt the edges back together. Who is right?
    (A) A only.
    (B) B only.
    (C) Both A and B.
    (D) Neither A nor B.

17. A binding repair will be made on a urethane bumper cover. Technician A wants to repair both the front and back of the part. Technician B wants to repair the front side only. Who is right?
    (A) A only.
    (B) B only.
    (C) Both A and B.
    (D) Neither A nor B.
18. None of the following plastics require an adhesion promoter EXCEPT:
    (A) urethane.
    (B) FRP.
    (C) SMC.
    (D) TPO.
19. Technician A says most engine parts are appearance parts. Technician B says polypropylene parts, such as fan shrouds and fender liners, should be finish sanded. Who is right?
    (A) A only.
    (B) B only.
    (C) Both A and B.
    (D) Neither A nor B.
20. An SMC panel needs a splice repair. Technician A wants to weld the replacement panel in. Technician B wants to use backing strips. Who is right?
    (A) A only.
    (B) B only.
    (C) Both A and B.
    (D) Neither A nor B.

Many late-model vehicles are equipped with sunroofs, which must sometimes be replaced during the collision repair process. This vehicle is outfitted with a panoramic sunroof made of a special tinted glass that helps keep the passenger compartment cool and blocks harmful ultraviolet (UV) rays.



Chapter 12

Glass

Objectives

After studying this chapter you will be able to:

- Describe the types of glass found on vehicles.
- Identify the specialized tools and materials used in glass service.
- Demonstrate the procedure for removing and replacing movable glass.
- Explain how to remove and replace fixed glass.

Technical Terms

banana knife
bone
cable knife
caulking gun
coated glass
cut-out knife
damming tape
dicing
drive away time
dry time
encapsulated glass
fixed glass
frit
garnish molding
glass cleaner
glass label
glass primer
heated glass
hook tool
laminated safety glass
lap shear strength
locking strip tool
lubricant
movable glass
oscillating knife
pinch weld primer
plastic paddle
power caulking gun
quarter glass
reciprocating knife
retainer
reveal moldings
run channels
safety glass
self-etching primer
setting blocks
suction cup
tempered safety glass
urethane adhesive
windshield knife
windshield wire tool

Introduction

Automotive glass allows the vehicle's occupants to see outside the vehicle while protecting them from the outside elements. On unibody vehicles, the glass may add to the structural strength of the unibody. This structural glass, as well as other glass that does not move, is called fixed glass. Glass that can change position is called movable glass. This chapter begins with a discussion of the types of glass used on a late-model vehicle. It then details the tools, materials, and techniques used to service automotive glass.

Types of Glass

Figure 12-1 shows the names of the various windows in a vehicle. All automotive windows are made of safety glass. ***Safety glass*** is designed to minimize the chances of injury if it is broken. Windshields are made of laminated safety glass. ***Laminated safety glass*** consists of two layers of glass with a layer of polyvinyl butyl plastic between them. When this type of glass breaks, the glass shards cling to the plastic rather than being thrown about the inside of the vehicle. See **Figure 12-2**. Laminated safety glass also resists impacts and prevents the vehicle's occupants from being thrown through the windshield. On vehicles equipped with a passenger-side air bag, the windshield acts as a backstop to support the inflated air bag. Depending on the vehicle type, windows other than the windshield may also be made of laminated safety glass.

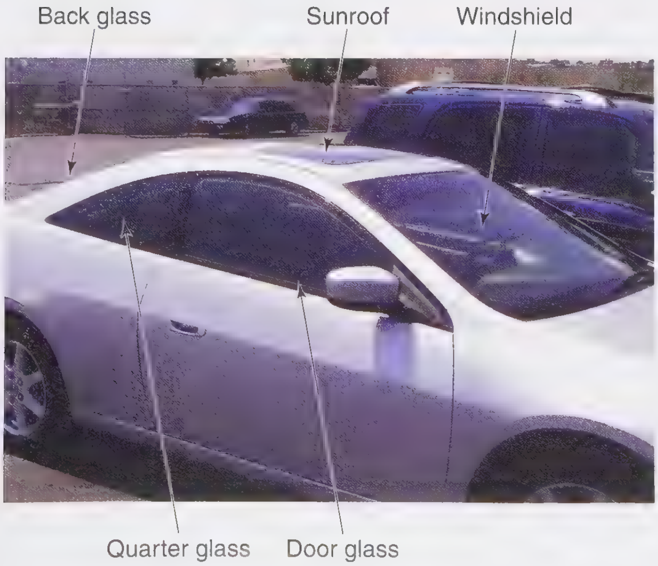


Figure 12-1. *Typical glass found on a late-model vehicle. If this vehicle had glass in the sail panel area, it would be called quarter glass.*

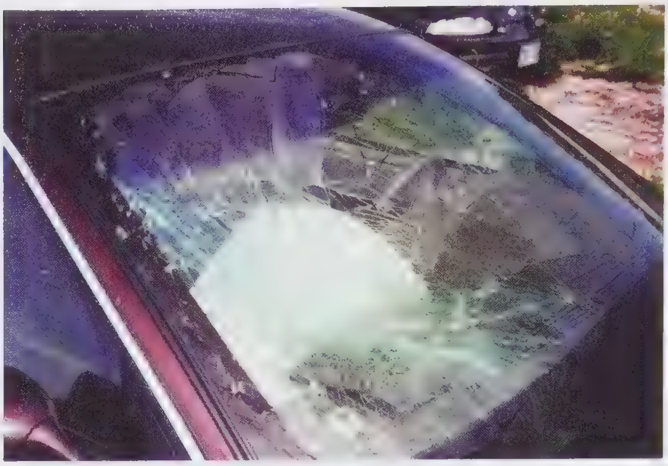


Figure 12-2. *When laminated safety glass breaks, the plastic layer holds the glass together.*

Tempered safety glass may be used for any window other than the windshield. ***Tempered safety glass*** is a single layer of glass that has been heated, or tempered, during manufacture. The tempering process gives the tempered glass increased strength. If tempered glass does break, it shatters into small cube-shaped pieces. Tempered safety glass breaks in a pattern called ***dicing***, **Figure 12-3**. Dicing helps minimize injury to the vehicle's occupants. Nevertheless, the pieces of broken laminated glass are sharp, so wear gloves when cleaning up broken glass.

Both lamented and tempered safety glass can be coated or heated. ***Coated glass*** has a chemical film that blocks light. A solar coating, which is used on some

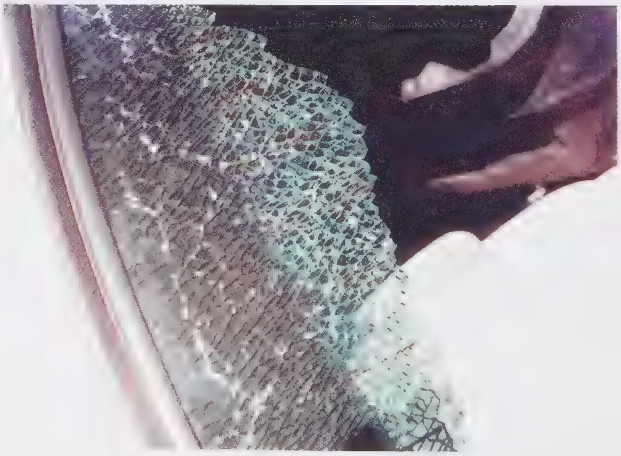


Figure 12-3. *Tempered safety glass breaks into a pattern called dicing.*

windshields, blocks UV light, protecting the interior. Privacy glass is coated to prevent someone outside the vehicle from looking into the passenger compartment. Privacy glass cannot be used on the windshield, and most states have laws regulating the darkness of the coating used on the front side windows, the rear side windows, and the back window. ***Heated glass*** may contain an electrical grid. This grid warms the glass, melting frost and removing moisture from the glass.

Encapsulated glass has a plastic frame that is molded around a piece of safety glass. The glass cannot be separated from the plastic frame. Encapsulated glass must be removed and installed as a unit. Windshields and quarter glass are common examples of encapsulated glass. ***Quarter glass*** is installed in the quarter panel, behind the door. It is typically found on two-door vehicles, but it may also be used on some four-door vehicles. See **Figure 12-4**.

Automotive glass is labeled to identify its type. **Figure 12-5** shows an example of a ***glass label***. The glass label includes the name of glass manufacturer, the type of glass (laminated or tempered), the date the glass was made, the plant the glass was made in, the DOT certification number, and the model number. The label may also include the glass manufacturer's logo.

Movable and Fixed Glass

Automotive glass can also be categorized as being movable or fixed. As the name implies, ***movable glass*** can roll up and down, slide backward and forward, or swing in and out. This type of glass is found on doors, quarter panels, pickup truck back glass, and rear hatches. ***Fixed glass*** does not move. All windshields are fixed glass. Encapsulated glass is also fixed.

Movable Glass

There are several types of movable glass, including rolling glass, sliding glass, hinged glass, and turning glass. Rolling glass is found on door windows. It moves, or rolls,

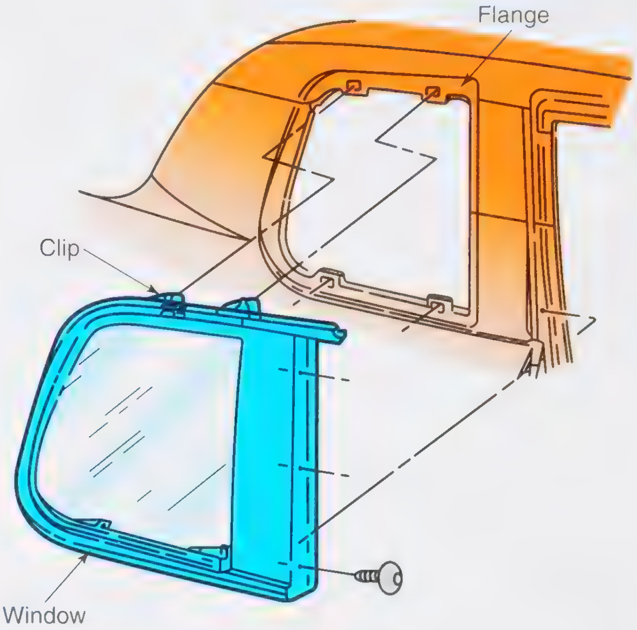

Flange
Clip
Window

Figure 12-4. *Encapsulated glass, such as this quarter glass, is a single assembly. The glass and the molding cannot be separated.*

This monogram, "bug" or "sandblast" appears on all glass parts:

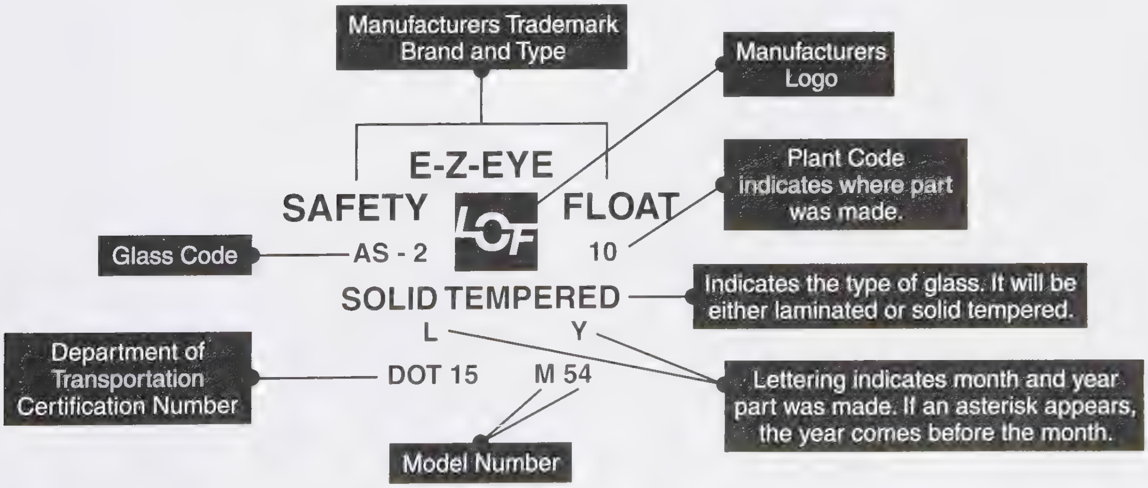

Manufacturers Trademark Brand and Type
Manufacturers Logo
E-Z-EYE
SAFETY
LOF
FLOAT
Plant Code indicates where part was made.
Glass Code
AS - 2
10
SOLID TEMPERED
Indicates the type of glass. It will be either laminated or solid tempered.
L
Y
Department of Transportation Certification Number
DOT 15
M 54
Lettering indicates month and year part was made. If an asterisk appears, the year comes before the month.
Model Number

Figure 12-5. *The glass label lists the manufacturer, plant code, type of glass, model number, date of manufacture, certification number, and glass code. (National Glass Association)*

up and down. This up-and-down movement is controlled by a regulator. The regulator can be operated manually or it can be operated by an electric motor. **Figure 12-6** shows a typical rolling door glass. The glass is attached to the regulator with bolts, rivets, or rollers. If the window glass has rollers, the glass will be bonded to a bracket that is attached to the rollers. **Figure 12-7** shows the parts of a riveted window glass.

Rolling glass moves up and down in ***run channels***. The run channels are lined with felt or rubber. On a sedan door, the window is encased in a window frame. The run channels on these vehicles extend from the top of the window frame nearly to the bottom of the door, so the window is braced by the run channel the entire length of travel. On a hardtop, which has no window frame, the run channels are inside the door only. When the door glass is rolled up, there is no bracing by a window frame.

Weather strip seals the movable glass to prevent air and water leaks. Weather strip on the outside of the window consists of a rubber strip covering a metal framework. The metal framework is clipped to holes or a lip in the door. Weather strip on the inside of the window is a rubber strip stapled or bonded to the door trim panel.

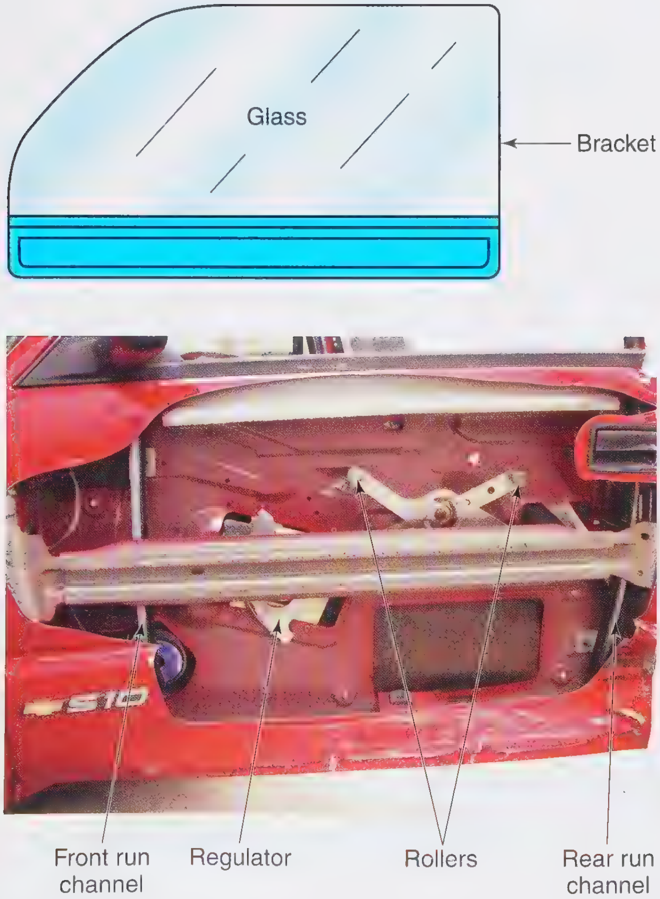


Figure 12-6. *The regulator moves the glass up and down in the run channels.*

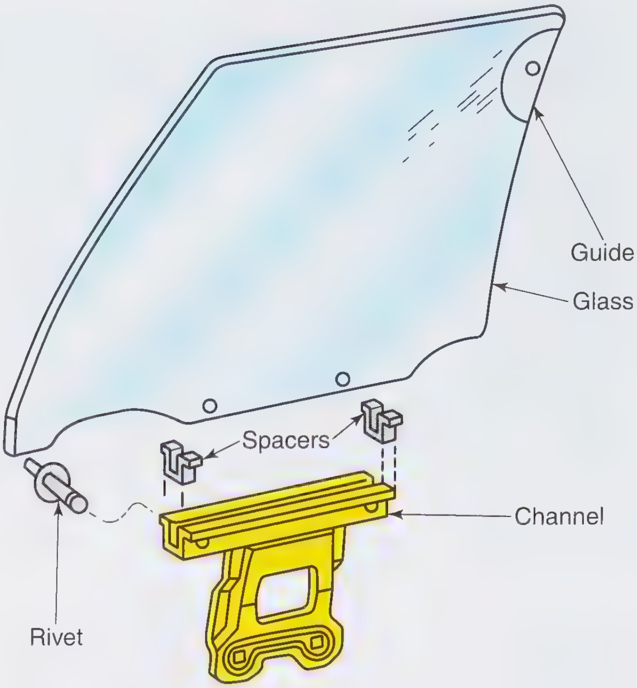


Figure 12-7. *In this example, the window is riveted to the bracket. In older vehicles, the door glass may be bonded to the bracket.*

A common example of sliding glass is the back window on a pickup truck. The window shown in **Figure 12-8** consists of two pieces of glass that slide away from the center. There is a latch in the middle to hold the glass shut. Sliding glass may also be found on some van doors, sunroofs, and quarter glass.

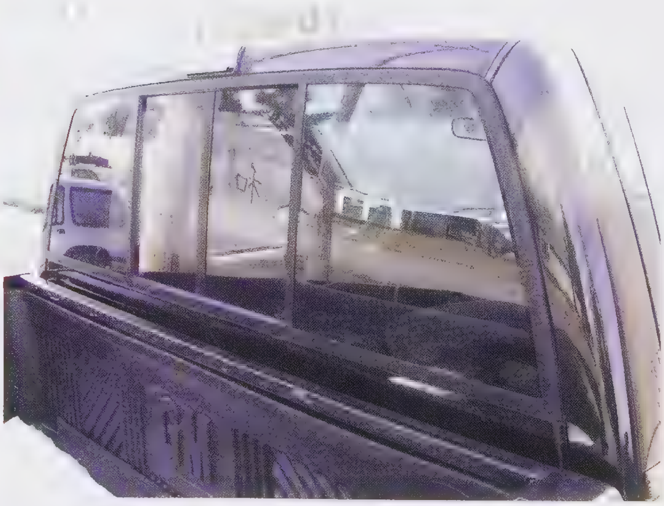


Figure 12-8. *This is the sliding back glass in a pickup truck. The two pieces of glass in the center of the window slide away from each other.*

Hinged glass may be found on quarter panel windows, extended cabs, and sunroofs. The hinges may be spring-steel strips that allow a small amount of movement or a simple hinge made of two C-shaped steel channels that are locked together.

If spring steel hinges are used, one end of the hinge is attached to the glass with plastic screws and nuts, and the other end is riveted to the vehicle. The window is held open or closed by a clasp. Like the hinge, the clasp is attached to the window with plastic screws and nuts, and riveted to the vehicle. On C-shaped steel channel hinges, one half of the hinge is bolted to the window and the other half is bolted to the vehicle's door or quarter panel. A clasp holds the glass open or closed.

Door vent glass, **Figure 12-09**, is turning glass. This type of glass turns on a pivot and seals against a gasket.

Fixed Glass

There are three types of fixed glass: bolted glass, rubber-set glass, and urethane-set glass. Quarter glass and pickup truck back glass may be bolted in place. A gasket that surrounds the bolted glass fits inside a metal frame. The metal frame has welded-on bolts. These bolts are inserted through holes in the body and secured with nuts. Note that it is actually the metal frame, not the glass, that is bolted to the vehicle. Some bolted glass has a layer of butyl tape between the metal frame and the vehicle to seal out moisture.

A rear door is shown in **Figure 12-10**. This door contains rolling glass and bolted glass. The bolted glass is surrounded by a gasket, which is held in place by the window frame of the door and the rear run channel for the rolling glass. The rear run channel is bolted in place. There is no butyl tape used with this type of bolted glass.

One type of rubber-set glass is shown in **Figure 12-11**. The rubber gasket surrounds the glass and seals the glass to the vehicle's body. The gasket contains a channel for the glass and a channel for the pinch weld.

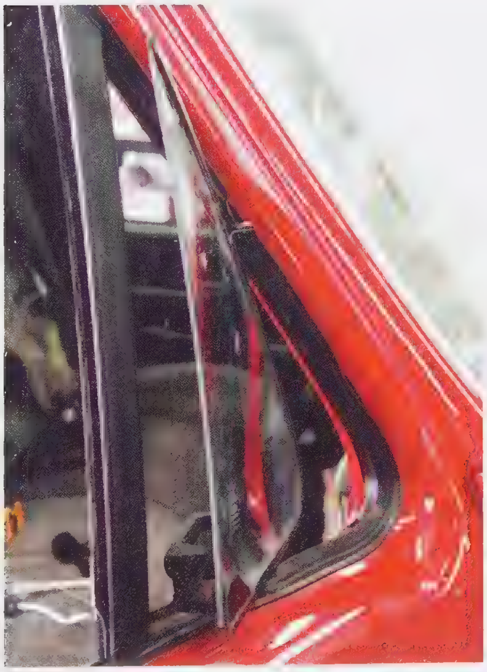


Figure 12-9. *This is a turning glass in a truck door.*

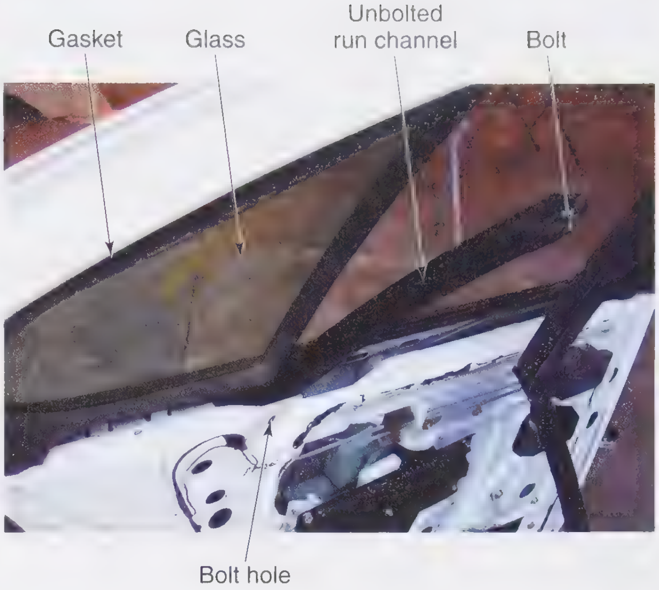


Figure 12-10. *This rear door has a movable glass and, behind it, a fixed glass. The run channel is partially removed. The run channel is bolted at the top of the window frame and at the door shell. The bolted run channel holds the glass and gasket in place.*

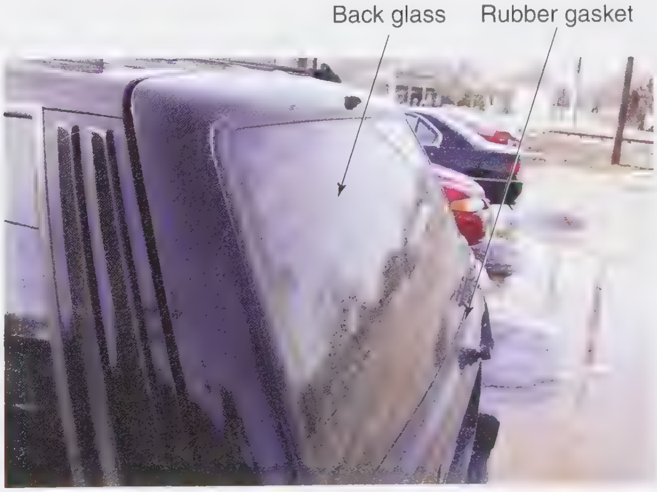


Figure 12-11. *This rubber-set back glass is held in place with a gasket.*

See **Figure 12-12A**. The pinch weld channel secures the gasket to the vehicle, and the glass channel holds the glass to the gasket. The glass is held in place by the tight fit between the glass, gasket, and pinch weld.

Figure 12-12B shows a cross section of a different type of gasket. This gasket has a channel for a locking strip. When the locking strip is installed, **Figure 12-12C**, it causes the gasket to expand, tightening the gasket on the glass and the pinch weld. Removing the locking strip creates a slight amount of play between the gasket and the glass, so the glass can be slipped out of the gasket during removal.

Modern vehicle windshields and most encapsulated glass are set in urethane. Urethane-set glass not only maintains the structural integrity of a vehicle during a collision, but it also supports a deployed passenger-side air bag.

NOTE

Older vehicles may have butyl tape-set glass. Butyl tape is very weak compared to urethane.

An improperly installed urethane-set windshield can be pushed loose from the pinch weld by the force of a passenger-side air bag deployment. If the windshield is pushed from the pinch weld, the window will not support the deployed air bag and the passengers could strike the dash during the impact. The parts of a urethane-set windshield are shown in **Figure 12-13**.

Urethane is degraded by sunlight. A ***frit*** is a black border around the perimeter of any urethane-set glass. It protects the urethane from sunlight damage. The VIN notch is a gap in the frit through which the VIN on the cowl can be viewed. The mirror button is bonded to the glass for the installation of the rearview mirror. The shade band minimizes the passage of light through the upper portion of the windshield.

Urethane-set glass may or may not have a molding. **Figure 12-14** shows the three types of urethane-set glass. In Figure 12-14A, the molding covers the gap between the glass and the edge of the pinch weld. In Figure 12-14B, the molding is smaller, so the gap between the pinch weld and the glass is not filled, although the molding does cover some of it. In Figure 12-14C, there is no molding, so the gap is entirely exposed. When cutting out a glass set as

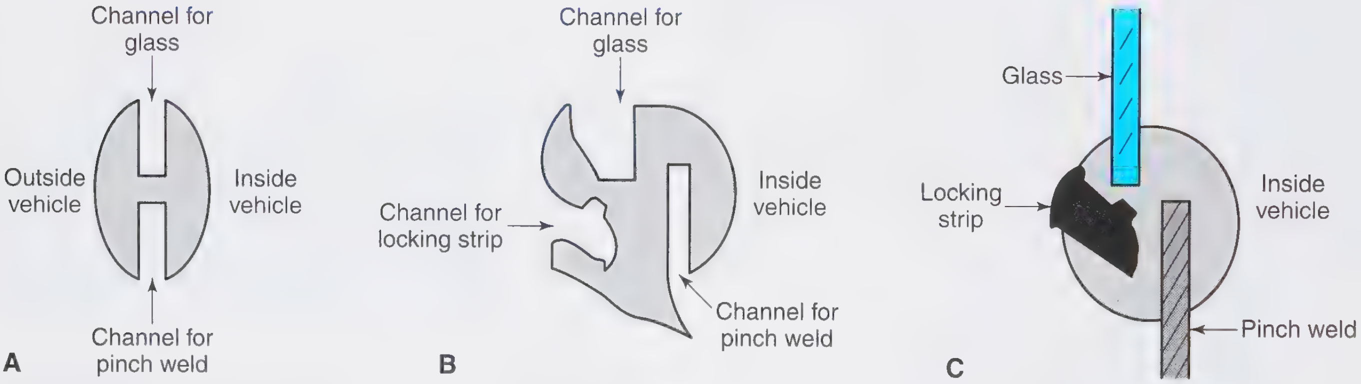

Channel for glass
Outside vehicle
Inside vehicle
Channel for pinch weld
A
Channel for glass
Channel for locking strip
Inside vehicle
Channel for pinch weld
B
Glass
Locking strip
Inside vehicle
Pinch weld
C

Figure 12-12. *A—This gasket has channels for the glass and the pinch weld. B—This gasket has a channel for a locking strip. C—Installation of the locking strip causes the gasket to tighten against the glass and the pinch weld.*

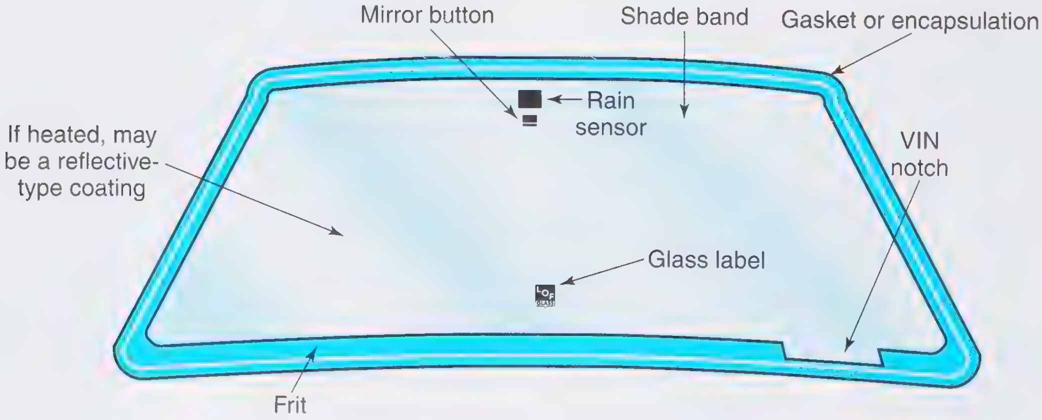

Mirror button
Shade band
Gasket or encapsulation
Rain sensor
If heated, may be a reflective-type coating
VIN notch
Glass label
Frit

Figure 12-13. *The parts of a urethane-set windshield include the frit, gasket, VIN notch, mirror button, and glass label.*

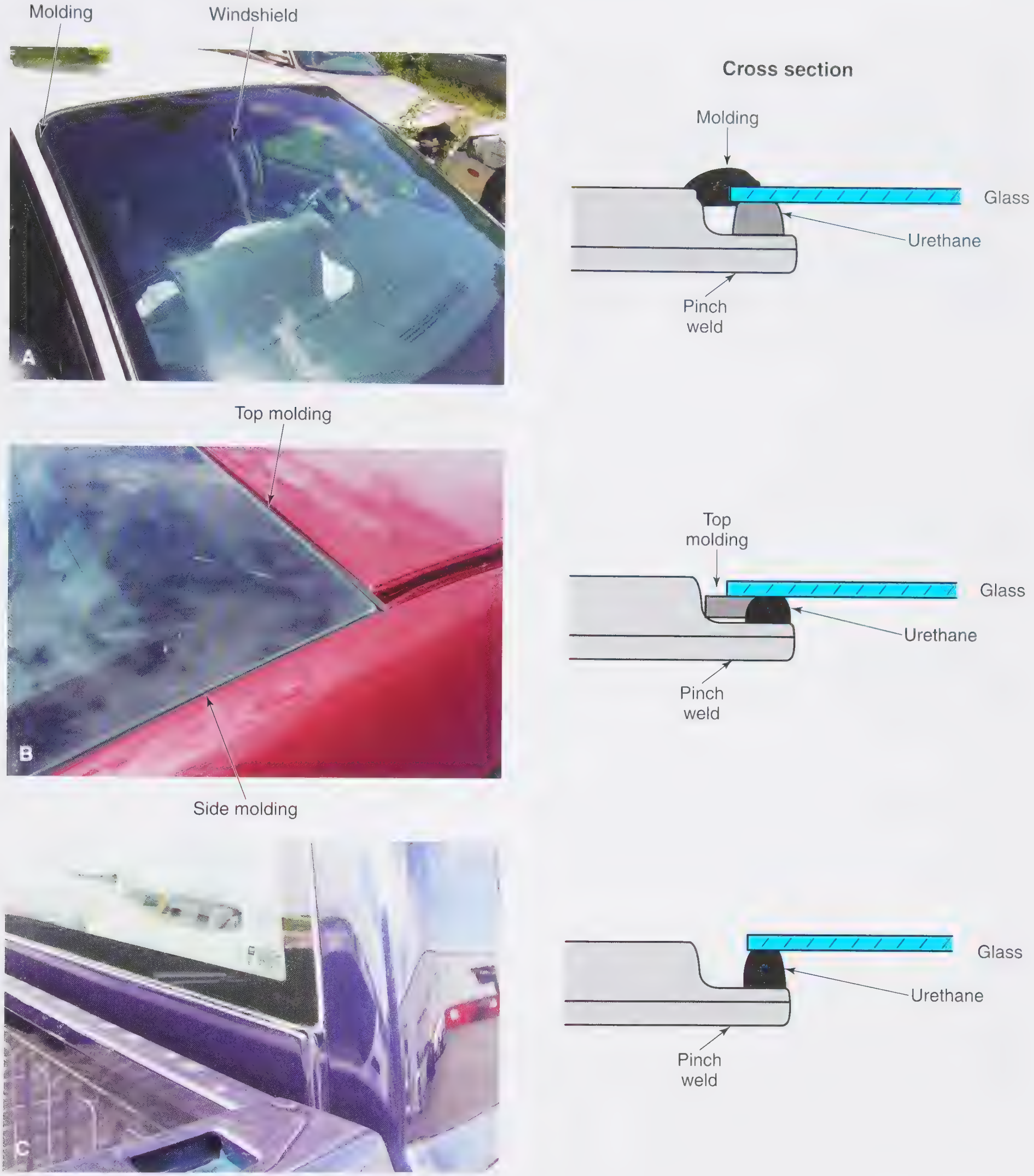

Molding
Windshield
A
Cross section
Molding
Glass
Urethane
Pinch weld
Top molding
B
Side molding
Top molding
Glass
Urethane
Pinch weld
C
Glass
Urethane
Pinch weld

Figure 12-14. *A—The molding attached to the glass fills the gap between the pinch weld and the glass. B—This molding is attached to the bottom of the glass with double-sided tape. The molding does not fill the gap between the pinch weld and the glass. C—This glass does not have a molding.*

shown in Figure 12-14B or C, extreme care must be taken to avoid nicking the paint. The molding may be made out of plastic or metal. Moldings around the outside of a windshield are called ***reveal moldings***. A windshield molding on the inside of the vehicle is called a ***garnish molding***. Plastic reveal moldings may be attached to the windshield as shown or fixed in the urethane that holds the windshield in place. Metal reveal molding was used on older vehicles.

Each component of installation contributes to keeping urethane-set glass in place. These components include the pinch weld, the primer on the pinch weld, the paint on the pinch weld, the urethane, the glass primer, the windshield and even the glass cleaner. A failure in any one of these components could cause the windshield or other urethane-set glass to fail during a collision.

Glass Removal and Installation Tools

Glass service tools can be divided into two groups: hand tools and power tools. For most applications, power tools are faster than hand tools. Nevertheless, hand tools can be used for most glass-related jobs. This section describes only the specialty tools needed for glass removal and replacement. Screwdrivers, sockets, wrenches, and other common hand tools are also required for most repairs.

Hand Tools

Several hand tools are designed to facilitate the removal and installation of automotive glass. A ***hook tool***, **Figure 12-15**, is used to remove the locking strip on rubber-set glass. The hook tool can also be used to break the seal between the glass and the gasket. Always avoid touching the glass—particularly the edge of the glass—with the hook tool. The glass can be scratched or broken if it is contacted by the metal tool.

A ***plastic paddle***, or ***bone***, can also be used to break the seal between the glass and the gasket. See **Figure 12-16**. Because the paddle is plastic, it will not scratch surfaces like the hook tool.

A ***cut-out knife***, or ***cable knife***, is shown in **Figure 12-17**. The cut-out knife blade is inserted from

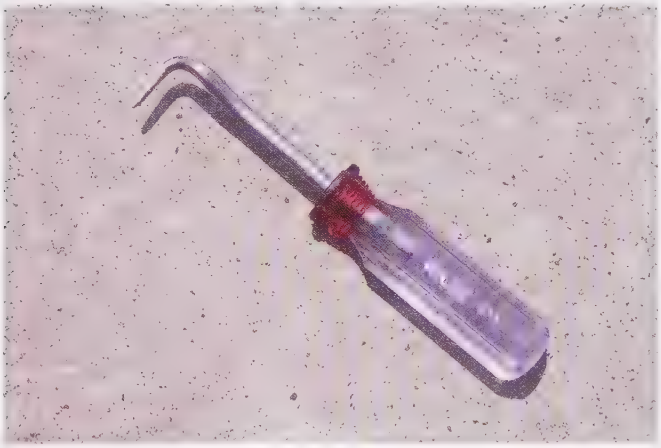


Figure 12-15. *A hook tool can reach inside a gasket to release the glass.*

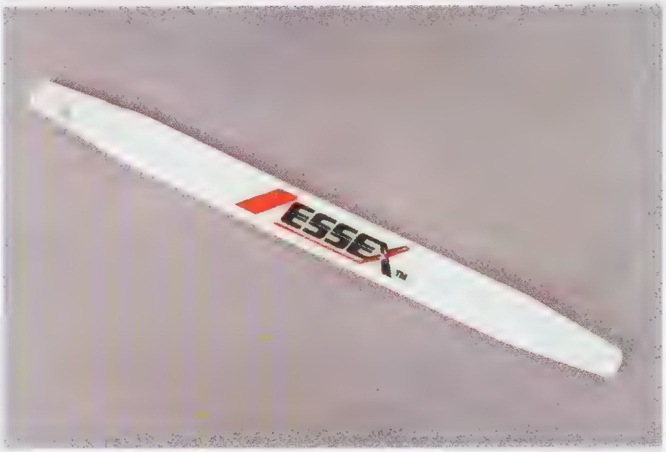


Figure 12-16. *This plastic paddle will not scratch the gasket or the paint.*

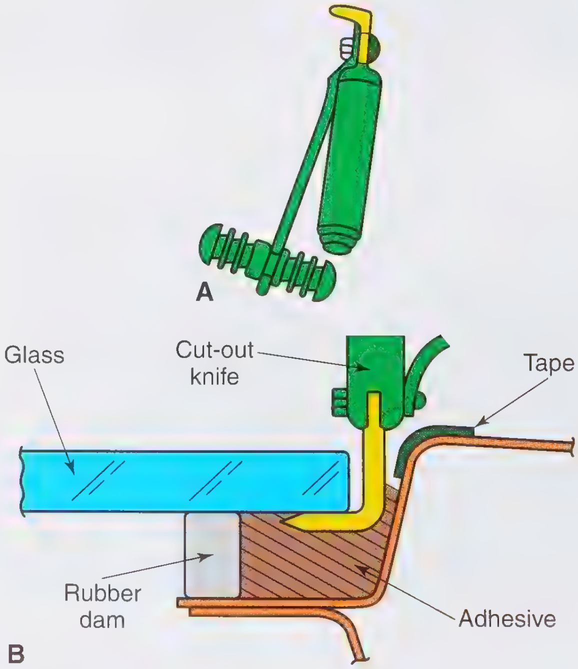


Figure 12-17. *A—Cut-out knife. B—The cut-out knife cuts the urethane, separating the glass from the pinch weld. One hand is used to pull the cut-out knife. The other hand is used to orientate the blade. The blade must be tilted slightly to keep the cut near the glass.*

outside the vehicle into the urethane holding a window in place. The knife has two handles so the technician can use one hand to pull the knife and the other to steady the blade. The length of the blade determines how much urethane is cut. The blade must be kept sharp. Dull or broken blades can be replaced. Keep the blade close to the glass, but do not allow it to contact the glass when cutting out a windshield. If the blade contacts the glass, the glass will break.

A ***banana knife*** is a long-handled razor blade holder. The banana knife is used from inside the vehicle to cut urethane. The razor blade is replaceable. A longer blade will make a deeper cut, however a long blade is weaker than a short blade, and a deeper cut requires more muscle power. Lubrication with water from a spray bottle will make cutting easier.

A ***windshield knife***, which is similar in function to a banana knife, is shown in **Figure 12-18**. This knife blade is inserted through the urethane and is then moved in a sawing motion to cut the urethane. Notice how the tip of the blade protrudes through the urethane to the outside of the vehicle. Careless sawing can allow the tip to contact painted or plastic surfaces, causing damage.

A ***windshield wire tool***, **Figure 12-19**, consists of two handles and a connecting wire. To use this tool, the wire is first inserted through the urethane. The wire is fed between the windshield and the windshield pinch weld. A handle is attached to the wire outside and inside the vehicle. The urethane is cut with a sawing action. If the windshield has cracks, do not let the wire get caught in a crack.

A ***suction cup*** can be used to affix a handle on glass. Ideally, glass should be carried by the edges. However, this might not be possible during installation or removal. To attach the suction cup to the glass, simply press the cup in place and pump the button to create suction. The cup should be clean. To release the cup, simply pull it away from the glass, breaking the seal. A suction cup is shown in **Figure 12-20.**

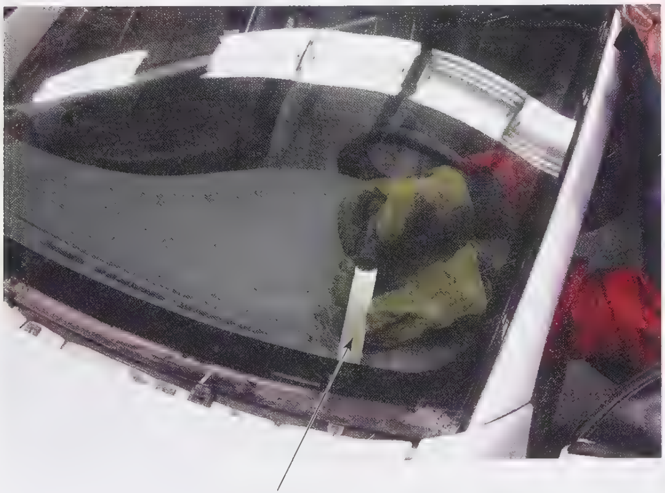


Figure 12-18. *The long handle of a banana knife allows the razor blade to reach into deep-set areas, such as the bottom of a windshield at the dash.*

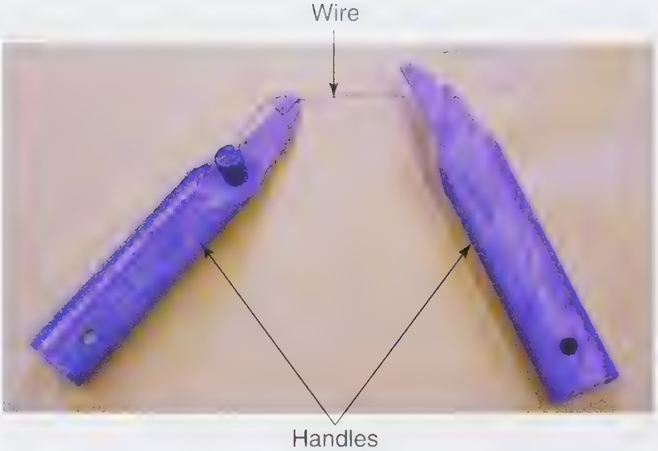


Figure 12-19. *The windshield wire tool consists of two handles connected by a wire. The handles are moved back and forth in a sawing action to cut urethane with the wire. When cutting near the windshield pillars, one technician can work the handles from outside the vehicle. When cutting near the middle of the windshield, two technicians will be required, one inside the vehicle and one outside the vehicle.*

The locking strip channel may need to be opened when installing the locking strip. The ***locking strip tool***, **Figure 12-21**, opens the channel so the locking strip can be set in place.

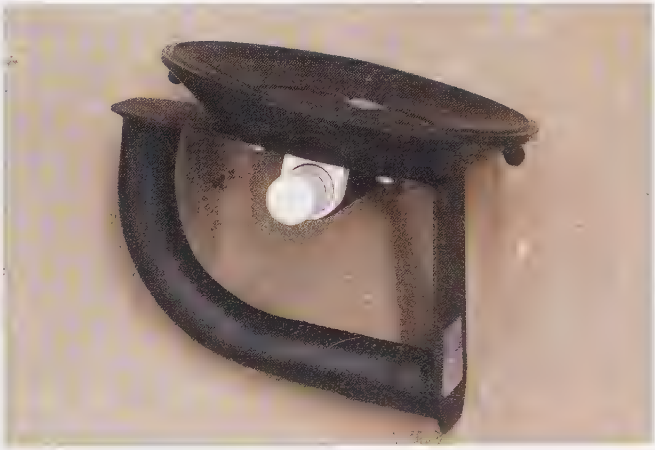


Figure 12-20. *A suction cup attached to the glass makes a handle. The suction cup is attached to the glass by pumping the button.*

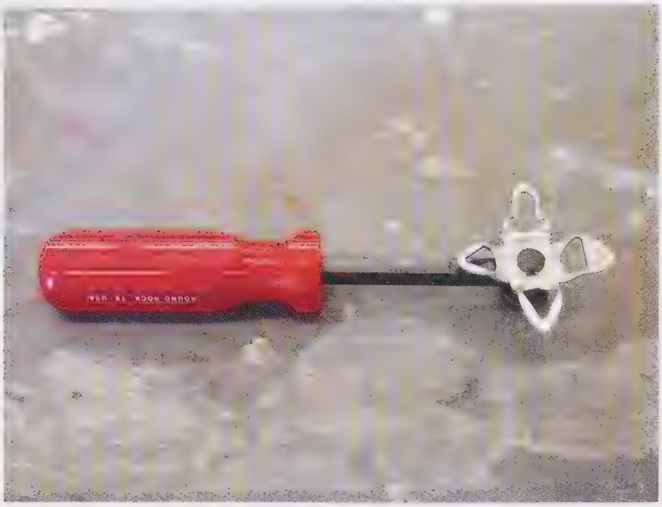


Figure 12-21. *The locking strip tool opens the gasket to allow the locking strip to be installed.*

Urethane can be applied with a ***caulking gun***, **Figure 12-22**. The urethane tube is opened and installed in the caulking gun. Pulling the caulking gun's trigger ratchets the plunger into the urethane tube, pushing the urethane out of the tube. Pushing on the gun's release lever removes the pressure on the plunger, stopping the flow of urethane. The speed of triggering determines how fast the urethane is pushed out of the tube.

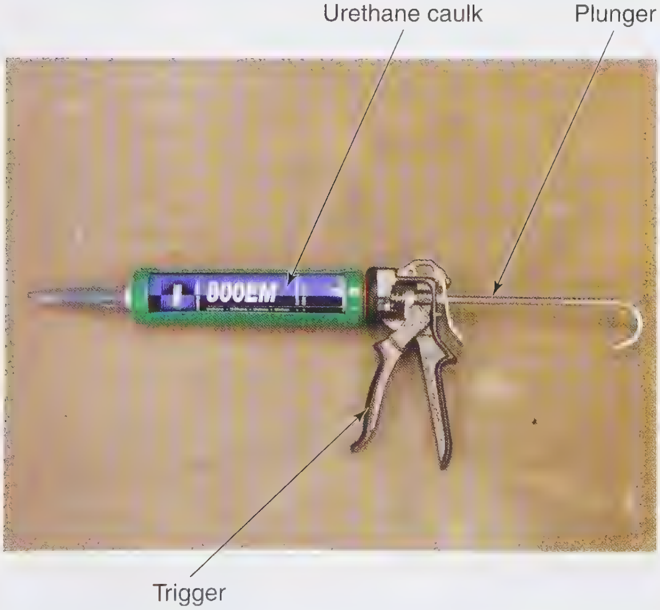


Figure 12-22. *This is a manual caulking gun. It takes practice and concentration to produce a uniform bead of urethane.*

Power Tools

Power tools used for glass removal and installation include the power caulking gun, the reciprocating knife, and the oscillating knife. These tools make glass removal easier and faster.

A ***power caulking gun*** is shown in **Figure 12-23**. The gun may be powered by air or electricity. It is easier to produce a uniform bead of urethane with a power caulking gun than with a hand caulking gun.

A ***reciprocating knife*** is shown in **Figure 12-24**. This type of knife may be powered by air or electricity. The blade moves in and out. Blades are available in several different lengths. The blade is inserted through the urethane from the inside of the vehicle. The blade is then used to saw through the urethane.

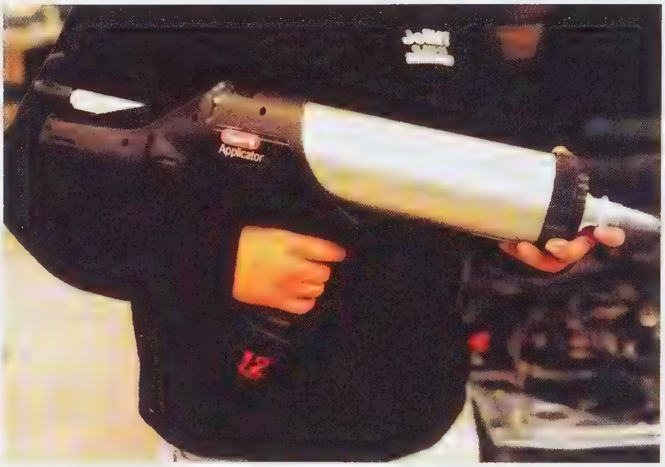


Figure 12-23. *A power caulking gun produces a uniform bead of urethane.*

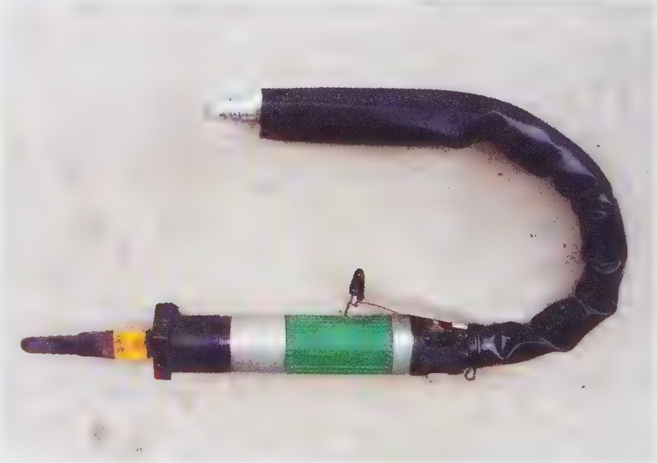


Figure 12-24. *The reciprocating knife's blade moves in and out.*

WARNING

Extreme care must be taken when using a reciprocating knife. The blade is sharp enough to cause serious injuries.

The blade is moved around the inside of the windshield or other glass, and the urethane is cut. It is important to hold the knife at the correct angle. If the knife is held at the wrong angle, too much stress will be placed on the blade, and the blade will break. The reciprocating knife has an angled area molded into the body of the knife. Holding this angled area against the glass sets the reciprocating knife at the proper angle. Water should be sprayed on the urethane while cutting to cool the blade and lubricate the urethane.

An ***oscillating knife*** has a blade that moves from side to side rather than in and out. An oscillating knife is shown in **Figure 12-25**. The knife can be used from inside the vehicle, or it can be fitted with an offset blade and used from outside the vehicle. With either type of blade, the angle at which the knife is held is important. The blade angle should minimize stress on the blade. If the angle causes the blade to bend, the blade will break. When cutting out a urethane-set glass, position the blade to cut close to the glass and try to stay away from pinch weld. Hitting the pinch weld with the blade will nick the paint and cause extra work repairing the damaged paint. The blades in both the reciprocating and oscillating knives should be kept sharp for maximum efficiency.

WARNING

Extreme care must be taken when using a reciprocating or oscillating knife. Their blades are sharp enough to cut through plastic, metal, and flesh.

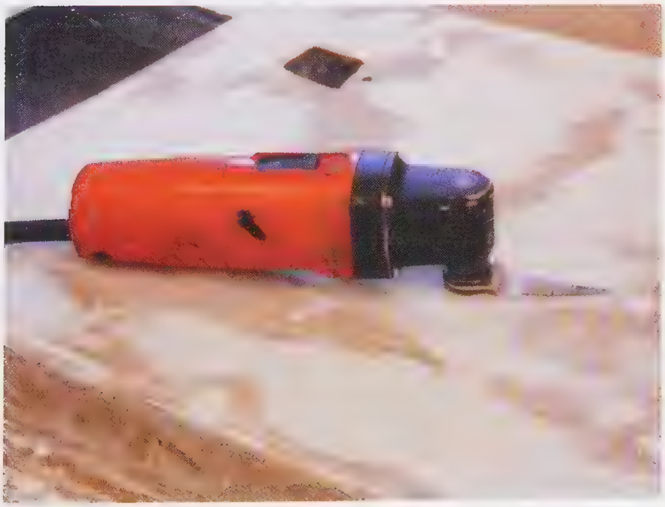


Figure 12-25. *The blade moves back and forth in an oscillating knife.*

Glass Repair Materials

There are a variety of glass repair materials on the market. Use only one manufacturer's products on any given job. Materials from different manufacturers may not be compatible. Many glass repair materials have a shelf life. Before using any product with a shelf life, make sure that the shelf life date has not passed.

Glass cleaner must be used to clean glass before it is installed. The cleaner used must be non-filming, which means it will not leave a residue on the glass. Any residue, or film, can interfere with bonding. The glass cleaner should not contain excessive amounts of ammonia or alcohol, and should not contain petroleum or silicone.

A ***lubricant*** is often used to help slip glass inside a gasket. Never use silicone spray lubricant in a body shop. It will contaminate surrounding surfaces and cause fish eyes when paint is applied to the vehicle. Lithium-based white grease, liquid soap and water, or glass cleaner may be used as a lubricant. Clean all lubricants off the glass before using an adhesive.

Glass primer is applied to glass to ensure a strong bond between the glass and the adhesive, and to block UV light. UV light is harmful to urethane. Most urethane-set glass has a black paint border, or frit, around its perimeter. This frit prevents UV light from harming the urethane. The glass primer has a specific dry time. ***Dry time*** is the amount of time required for the solvents to evaporate from a paint or primer. Until the solvents evaporate, the paint or primer is not fully adhered to the surface.

Self-etching primer must be applied to any bare metal on the pinch weld before the glass is installed. Cutting out the windshield may nick the paint, exposing the metal. Always inspect the pinch weld for bare metal and treat bare metal with a self-etching primer. The self-etching primer also has a dry time.

A ***pinch weld primer*** is used to treat self-etching primer or paint where urethane will be applied to the pinch weld. The pinch weld primer will help form a strong bond between the urethane and the metal of the pinch weld. The dry time for pinch weld primer may vary from product to product. Be sure to follow the manufacturer's recommendations. Pinch weld primer should not be applied to fresh cut urethane.

Damming tape is used to form a barrier to prevent urethane from squeezing out from under the glass. Damming tape is made from foam or butyl. Butyl damming tape is available in various sizes and shapes. If butyl damming tape is used, it is applied as a border around the area where the urethane will be applied. The most useful damming tape is 5/16" square.

Low-viscosity urethane will slide off the vehicle if not held in place by damming tape. High-viscosity urethane is thick enough to stay put once it is applied to the vehicle. Therefore, damming tape is not needed with high-viscosity urethane.

Urethane adhesive may be a one-part or two-part product. One-part urethane is the most common type. It cures by reacting with the moisture in the air. Two-part urethane cures through a chemical reaction. Cured urethane has high lap shear strength. ***Lap shear strength*** is the amount of force required to break the urethane. Butyl tape has a lap shear strength of 10–15 PSI, while cured urethane has a lap shear strength of 500–750 PSI. The curing of urethane is dependent on time, temperature, and type of urethane. A fast-cure, two-part urethane will cure in one hour. A one-part urethane may cure in two hours at room temperature. Lower temperatures increase cure time. Because the windshield maintains the structural integrity of the vehicle, the customer should not drive the vehicle until the urethane has cured. ***Drive away time*** is the same as cure time.

Glass Service

The following section explains how to remove and install various types of automotive glass. Unbroken glass may need to be removed during body repairs. For example, when installing a quarter panel, the quarter glass or back glass may have to be removed so the quarter panel can be spliced at the sail panel. Any time glass is removed, there is the possibility of breakage. Breakage is most common when a metal tool contacts the edge of the glass. Glass may also break if it is stressed during removal. Broken glass slivers will fly through the air. The technician should wear leather gloves, safety glasses, and long sleeves when working with glass.

Rolling Glass

To remove rolling glass in a door, roll down the window and remove the door trim panel. If necessary, remove the window crank handle and any visible screws. Disconnect any accessible switches. Pop the retainers out from the edges of the door trim panel. There may be additional retainers on the interior of the panel. Remove the door panel and the water seal.

On doors with a window frame, remove the run channel liners as shown in **Figure 12-26**. If the run channel liner is installed with screws, remove the screws and then remove the channel liner. Some window run channels are bolted in place at the top, bottom, or sides. Remove the bolts to remove these channels. Some run channels are not removable. On some vehicles, one of the run channels is welded to the door shell and the other run channel is bolted in place. To remove the window, remove the bolted run channel. This will allow you to maneuver the window enough to remove it.

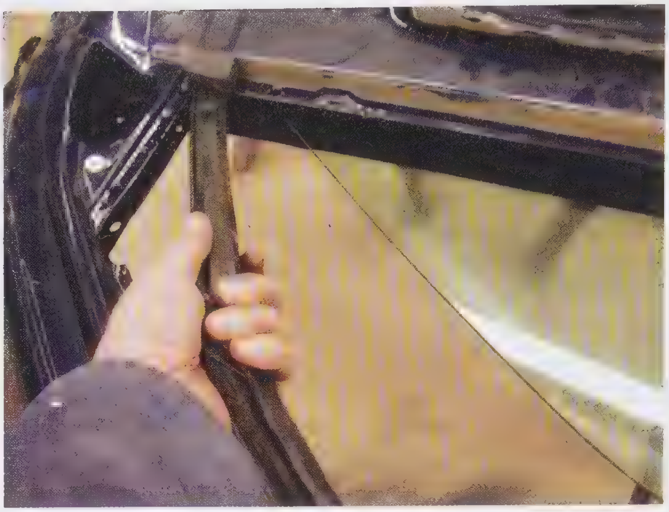


Figure 12-26. *To remove some types of rolling glass, the run channel is pulled out. This provides enough play around the glass to remove it.*

Raise the window to access the rivets, bolts, or brackets that hold the window to the regulator. If the window is secured with rivets, use a center punch to knock out the mandrels. Then drill out the rivets. The drill bit should be slightly larger than the diameter of the rivets' center hole. If the window is bolted in place, remove the bolts. If the window is held in place by a bracket attached to rollers, the bracket can be removed in one of two ways. One type of bracket has notches that allow it to be slipped off the rollers. The other type of bracket does not have notches. Instead, it must be moved far enough that the rollers clear the end of the bracket.

On one type of door, you must remove the turning glass before removing the window. The turning glass is part of the front run channel. The turning glass and run channel assembly must be tilted to the proper angle to remove it from the door. The removal of the front run channel will allow the glass to be moved enough that the rollers reach the notches or the end of the bracket. Some door designs require unbolting or otherwise moving the regulator to release the glass.

Once the glass has been released from the bracket, it can be slid out of the door. Most door glass has a slight curve, and it should be removed toward the inside of the vehicle. Some glass has a retainer that secures it in the run channel. See **Figure 12-27**. This ***retainer*** is a plastic clip that snaps around the edge of the glass. Pulling the glass toward the front of the vehicle will pull the retainer out of the run channel. On a vehicle that does not have a window frame, the glass can simply be unbolted and pulled out. Maneuvering room inside the door may be limited. Try many different angles if the glass is difficult to pull out.

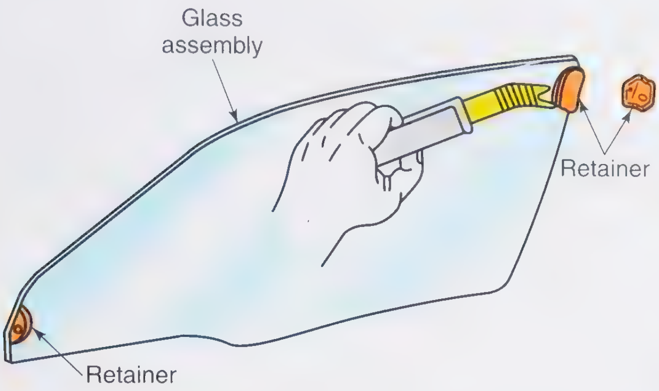


Figure 12-27. *The retainer holds the glass in the run channel. The glass and retainer must be pulled out of the run channel.*

To install rolling glass, maneuver the glass inside the window frame and into the door. Line up the regulator. Install the rivets or bolts, or slip the bracket into the rollers. Install the run channel liners. The liners may need to be lubricated to slide in place. Use liquid soap. If the window has a retainer, pull the glass back toward the rear of the vehicle to set the retainer in the run channel. It may take considerable effort to force the retainer into the run channel. Push the window straight. Pushing at an angle could break the window. With the glass in place, roll the window up and down to check for binding and sealing. Finally, reinstall the trim panel.

Sliding Glass

Sliding glass is set in a frame. The frame and glass must be removed as a unit. In some vehicles, individual parts may be available, allowing you to replace just the glass or just the frame. In other cases, the sliding glass and frame are replaced as a unit.

Sliding glass may be bolted in place or set in rubber. Instructions for rubber-set sliding glass are presented in a later section. To remove bolted sliding glass, first remove any interior panels that block access to the fasteners. Then, remove the bolts or nuts that secure the sliding glass unit to the vehicle. There will be butyl sealant between the sliding glass frame and the vehicle. The butyl sealant will leave a stringy, sticky residue when the glass is pulled away from the vehicle. Use a plastic putty knife to remove the remaining butyl sealant from the window opening.

To install bolted sliding glass, first apply butyl tape around the window opening in the same area butyl tape was placed at the factory. Then slide the bolts through the bolt holes and carefully tighten the fasteners so that equal pressure is applied around the glass. Replace the trim that was removed for access.

Hinged Glass

Hinged glass is often attached with plastic screws. See **Figure 12-28**. To remove hinged glass, first unscrew the clasp from the glass. Then remove the screws holding the hinges to the glass.

CAUTION

Remove the screws holding the hinges to the glass carefully. These screws are made of plastic and are easily stripped.

If the screws will not come out, the clasp, hinges, and glass can be removed as a unit. Remove the interior trim. Pop rivets used to hold the spring hinged glass in place on the vehicle. Drill out the pop rivets and remove the glass as a unit. On a C-hinge, unbolt the clasp and lift out the window. Then slide the C-hinges apart by moving the glass forward.

To install new hinged glass when the hinges and clasp have been removed from the vehicle, screw the clasp and hinges to the glass and then set the glass in place on the vehicle. Use a rivet gun to set pop rivets to hold the clasp and hinges to the vehicle. If the hinges and clasp were left on the vehicle, simply install the screws that hold the glass to the hinges and clasp.

On a C-hinge, screw the clasp to the window, slide the C-hinge on the window into the C-hinge on the vehicle, and pop rivet the clasp to the vehicle. If the C-hinge has been removed from the vehicle, reinstall it before installing the glass.

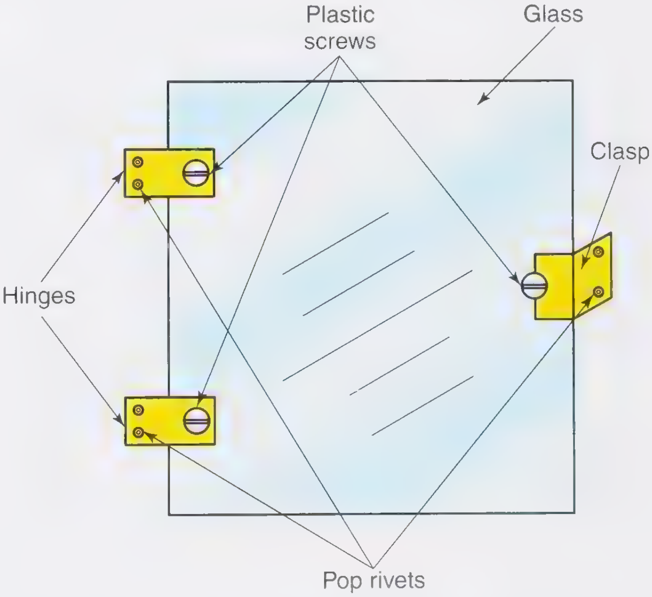


Figure 12-28. *The hinges and clasp are attached to the glass with plastic screws and to the body with pop rivets.*

Turning Glass

Turning glass is secured by a pivot. The pivot may be bolted at the top of the door window frame and to the inside of the door. In some cases, it may be bolted at the top of the window frame only. A pivot bolted at top and bottom requires that the door panel be removed to remove the turning glass. Unbolt the top and bottom pivots and twist the glass to remove it. If only a top bolt is present, removing the one bolt will allow the turning glass to be removed.

Bolted Fixed Glass

A rear door window may have both rolling and fixed glass. To remove bolted fixed glass in a rear door, first remove the rolling window glass. The bolted fixed glass is held in place by the rear run channel. Removing the rear run channel will allow the fixed glass to be pulled out of its gasket. See **Figure 12-29**. Some bolted fixed glass is held in place with additional bolts besides those holding the rear run channel in place. To install fixed bolted glass, slide the glass into the gasket and bolt the run channel in place.

Rubber-Set Glass, No Locking Strip

Rubber-set glass should be removed as a unit. However, if the gasket will not be reused, it can be cut out with a knife. The following instructions are for removing the glass and gasket together, and reusing the gasket.

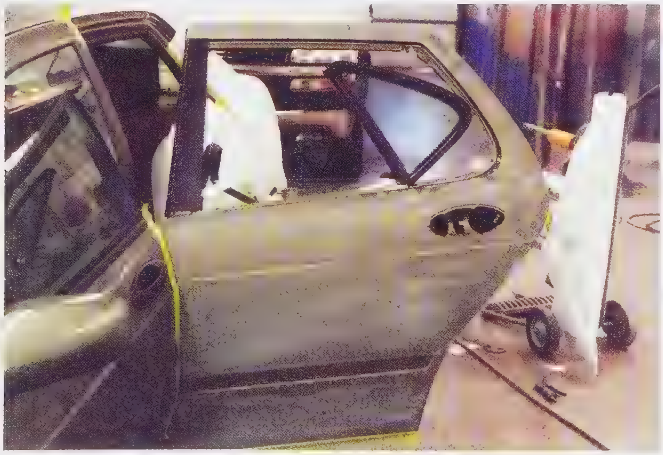


Figure 12-29. *There are two bolts on the top of the window frame and one bolt in the run channel. With these removed, the fixed glass can be taken out.*

To remove the glass:

1. Remove the interior trim that blocks access to the gasket.
2. Sunlight and heat may cause the gasket to seal to the vehicle pinch weld and the glass. Break the seal by inserting a bone between the gasket and the vehicle or glass, and then pushing the bone all around the gasket. Break the seal between the gasket and the pinch weld, as well as the seal between the glass and gasket on both the inside and outside of the vehicle.
3. Starting from a corner inside the vehicle, pull the bottom of the gasket toward you. Lift the corner of the gasket from the pinch weld. Push the corner of the gasket and the glass toward the outside of the vehicle. See **Figure 12-30A**. Once the corner is loose, the rest of the gasket and glass can be easily removed.
4. Working inside and outside of the vehicle as shown in **Figure 12-30B**, separate the gasket and glass from the pinch weld by pulling out and pushing out.

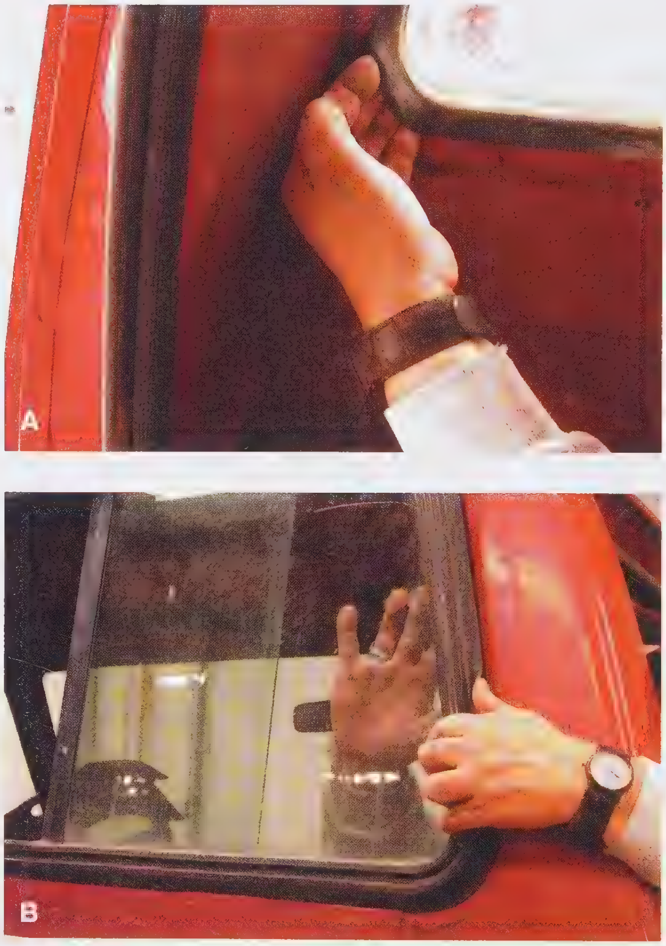


Figure 12-30. *A—To remove a rubber-set glass, first break the seal and then push one corner of the gasket out. B—With the first corner released, pull and push the gasket away from the rest of the pinch weld.*

Once one side of the gasket and glass is out, the rest of the gasket and glass can be pulled away from the pinch weld.

To install rubber-set glass:

1. Install the gasket around the window.
2. Insert a piece of rope into the pinch weld channel of the gasket. The rope ends should meet at the bottom center of the window.
3. Set the gasket's pinch weld channel in place on the bottom pinch weld. The ends of the rope should be inside the vehicle.
4. Set the glass/gasket so that it leans against the pinch weld. This will require someone on the outside to hold the glass in place and apply slight pressure.
5. Hold one end of the rope in each hand and pull the ends of the rope away from each other along the bottom of the window. Continue pulling the rope out along the sides of the window and across the top, releasing the rope from the pinch weld channel. Pulling the rope out of the pinch weld channel in the gasket will curl the gasket over the pinch weld, setting the gasket/glass in place. See **Figure 12-31**.

Rubber-Set Glass, Locking Strip

Rubber-set glass with a locking strip can be removed by cutting out the gasket or by removing the glass from the gasket.

To remove the glass:

1. Remove the locking strip. An old, weathered locking strip may break during removal. If the locking strip breaks, use a hook tool to pry the broken end of the locking strip from the locking strip channel.
2. Use a bone to break the seal. Push the bone all around the window in between the gasket and glass and between the gasket and pinch weld. This should be done both inside and outside the vehicle.
3. Working from inside the vehicle and starting at the corner with the largest radius, peel the gasket back and push the glass out. This will release a corner of the glass.
4. Work your way around the window, peeling the gasket back and pushing the glass out from inside the vehicle.

To install the glass:

1. Clean the pinch weld.
2. If the original gasket will be reused, check it for cracks or brittleness. Replace cracked or brittle gaskets and locking strips. Cracked or brittle gaskets or locking strips will be difficult to install without breaking, and they may not seal well enough to keep water out.
3. Position the gasket's pinch weld channel on the pinch weld.
4. Apply a lubricant to the glass channel of the gasket.
5. Place the bottom of the glass in the glass channel.
6. Using a plastic paddle, slip the glass into the channel.
7. Work your way around the gasket, slipping the glass into the channel.
8. Replace the locking strip. Lubrication may be needed. A locking strip tool helps open the channel, allowing the locking strip to be inserted. If a locking strip tool is not available, a plastic paddle can be used to facilitate installation.

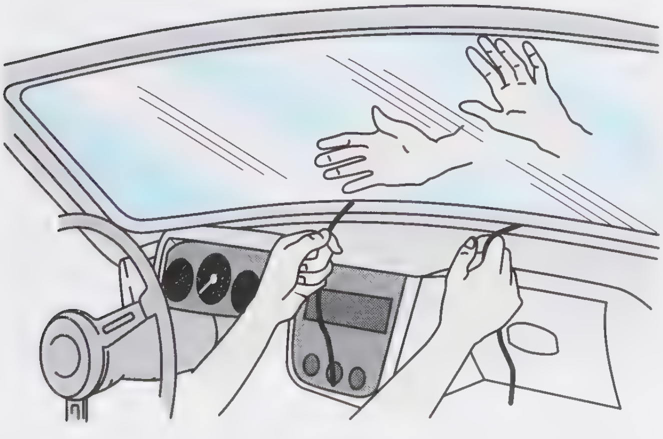


Figure 12-31. *Pulling on the rope curls the pinch weld channel into place.*

Urethane-Set Glass

There are two methods used to replace urethane-set glass: the partial cut-out method and the full cut-out method. Most vehicle manufacturers recommend only the full cut-out method. In the full cut-out method, the urethane layer between the glass and the pinch weld is cut and the windshield or back glass is removed. Then the urethane remaining on the pinch weld is cut so that only 1/16" (1–2 millimeters) remains. New urethane is applied to the pinch weld before the glass is reinstalled.

In the partial cut-out method, the urethane is cut close to the glass so that most of the urethane remains on the pinch weld. If the urethane is in good shape and there isn't any evidence of leakage, fresh urethane is applied on top of the existing urethane. The difference between the methods is shown in **Figure 12-32**.

The steps in the full cut-out method are listed below:

1. Remove any moldings, trim, or windshield wipers that would prevent glass removal. On some vehicles, the cowl vent panel must be removed before the glass is removed.
2. Disconnect any electrical wires on heated glass.
3. Tape off the air vents inside the vehicle to keep debris out. Apply tape to the fender and hood edges. Cover the inside of the vehicle with a blanket to protect the seats and dash.

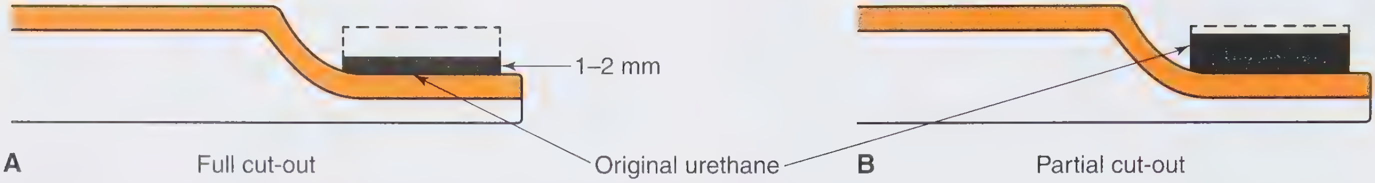


Figure 12-32. *A—In the full cut-out method, most of the original urethane is removed. B—In the partial cut-out method, most of the original urethane remains.*

4. Using a suitable knife and working from inside the vehicle, cut the existing adhesive between the glass and pinch weld. See **Figure 12-33**.
5. Remove the glass.
6. Cut the remaining urethane so that approximately 1/16" (1–2 millimeters) remains. Be careful not to cut into the paint and expose the bare metal. See **Figure 12-34**.

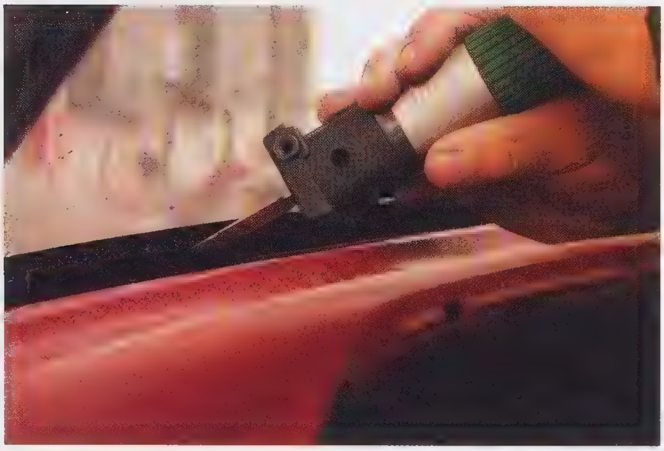


Figure 12-33. *Cut the urethane from inside the vehicle. Cut close to the glass and do not nick the paint in the pinch weld.*

Figure 12-34. *Body filler will be a weak link in a pinch weld repair. Do not put urethane over body filler.*

7. Closely examine the pinch weld for rust or bare metal. If rust is present, sand the area and apply a self-etching primer. Severe rust may require extensive metal repair. Bare metal areas should also be treated with self-etching primer. Allow the self-etching primer to dry according to the manufacturer's recommendations.
8. If the original glass is to be reused, carefully remove the urethane from the glass. Do not scratch the frit. After removing the urethane, clean the glass with an approved glass cleaner.
9. Test fit the new glass. Some windshields have ***setting blocks***, which are placed at the bottom of the glass, **Figure 12-35**. Position the glass on these blocks. Some windshields have alignment marks.

   Check the alignment. The glass should be equal on both sides of the alignment marks. The VIN should be visible. When the alignment is correct, put masking tape on the glass, the roof, and the windshield pillars as shown in **Figure 12-36**. This tape will help you realign the window after the adhesive is applied. Cut the tape so that it remains on the glass and on the vehicle. After cutting the tape, remove the glass from the vehicle.

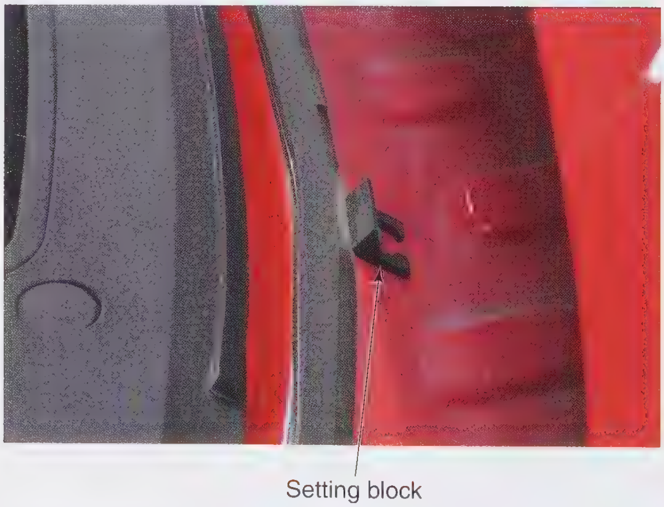


Figure 12-35. *The bottom of the windshield rests on setting blocks.*

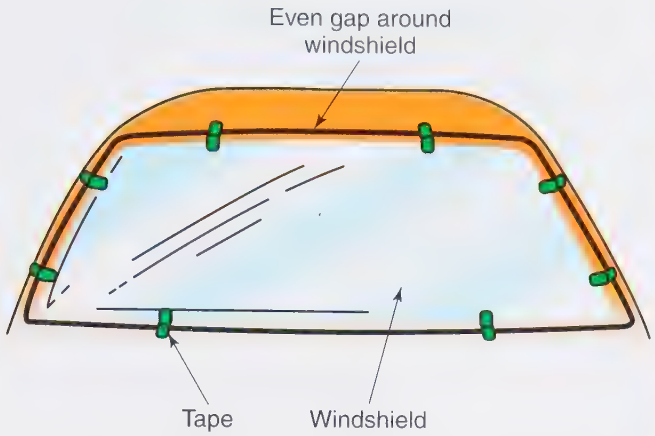


Figure 12-36. *The gaps between the windshield pillars and the windshield should be equal, and the gap at the top of the windshield should be even.*

10. Apply pinch-weld primer to the entire area where urethane will be placed. Do not touch the pinch-weld primer area.
11. Prepare the windshield. A new windshield must be trimmed. There is generally a small amount of the plastic laminate layer protruding from the glass. Cut off this plastic layer with a razor blade. Clean the windshield. If a molding is required, fit the molding around the windshield. Use tape on the outside of the molding to hold it in place. Clean the window again and apply a glass primer. Do not touch the inside of the glass once the glass primer is applied.
12. Apply the urethane to the pinch weld. Cut the nozzle in a “V” as shown in **Figure 12-37**. Apply the new urethane on top of the original urethane and the pinch weld primer, **Figure 12-38**.
13. Use the tape to align the new glass. Set the windshield in place at the cowl and then ease the windshield down at the top. It is critical that the glass be set in place and not lifted from the urethane after it contacts the urethane.
14. Use hand pressure on the center of the glass to move it into position. Do not put pressure on the edges of the glass. If the edges of the glass can be seen, check for contact between the urethane and the glass.
15. Some moldings are designed to adhere to the fresh urethane. Install these moldings. The molding may need to be taped in place until the urethane cures.
16. Reinstall the wipers and other trim.
17. Observe the drive away time before driving the vehicle.

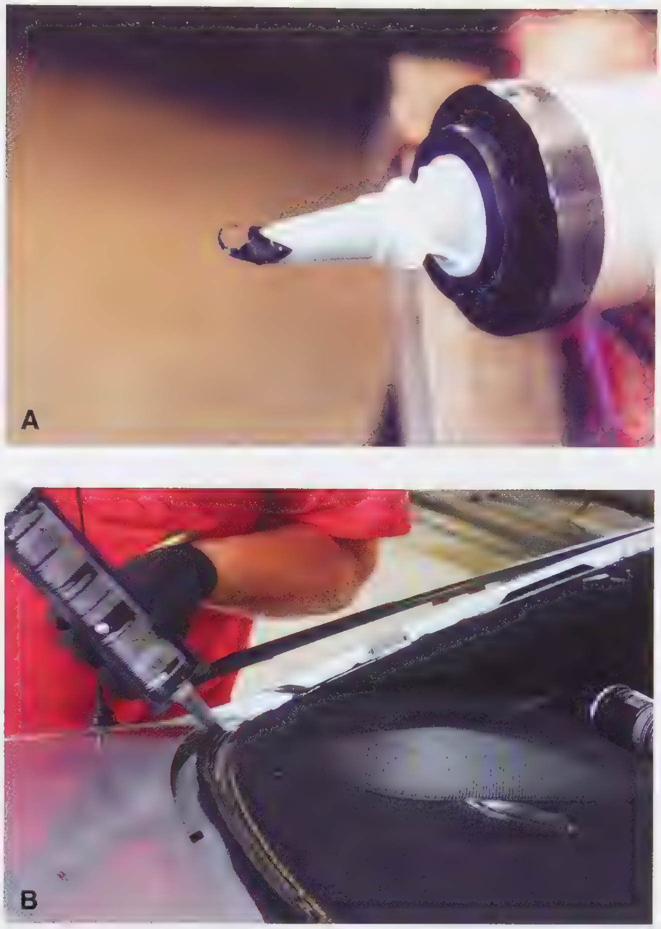


Figure 12-37. *A—The V notch in the nozzle will apply the proper amount of urethane to the pinch weld. B—Notice how the urethane is stacked up as it is applied to the pinch weld.*

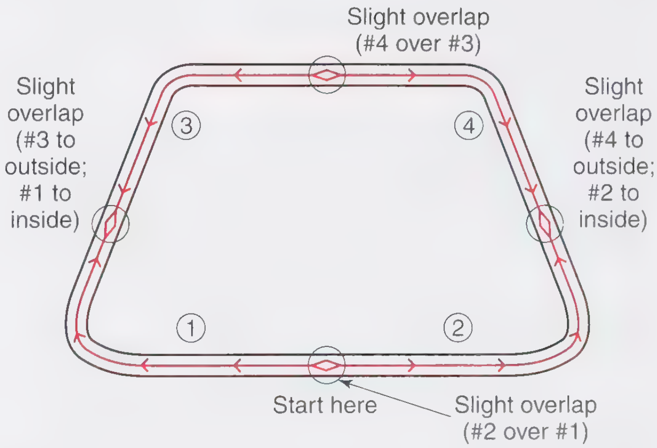

Slight overlap (#4 over #3)
Slight overlap (#3 to outside; #1 to inside)
Slight overlap (#4 to outside; #2 to inside)
③
④
①
②
Start here
Slight overlap (#2 over #1)

Figure 12-38. *Follow this pattern when applying urethane to a windshield or back glass opening.*

Encapsulated Glass

The removal and replacement of encapsulated glass is very similar to that of urethane-set glass. One difference is that if the encapsulated glass is to be reused, extra care is needed during removal. For example, cutting out an encapsulated quarter glass usually requires some type of power knife. If the knife contacts the molding, it will cut the molding, ruining the encapsulated glass. When cutting out encapsulated glass, work from inside the vehicle. Insert the blade just deep enough to cut the urethane. Careless cutting can be costly. Encapsulated glass installation is shown in **Figure 12-39**.

Leak Checks

Leak checks can be performed on original glass and, after the proper cure time, on new installations. Some leaks may be detected when driving the vehicle because the moldings move due to wind force. There are three methods of leak detection: water, air, and ultrasonic.

In a water test, water from a hose is simply sprayed onto the molding around the outside of the glass. Water drops inside the vehicle indicate a leak.

To air test for leaks, spray the molding around the outside of the glass with soapy water. From inside of the vehicle, direct a stream of compressed air at the perimeter of the glass. Bubbles in the soapy water indicate leaks.

An ultrasonic signal generator locates leaks by sending out inaudible sound waves. The generator is set up inside the vehicle. The sound waves will pass through any opening between the glass and the urethane. The detecting probe is moved around the perimeter of the glass outside the vehicle. The probe will signal if sound waves are detected outside the vehicle, indicating a leak.

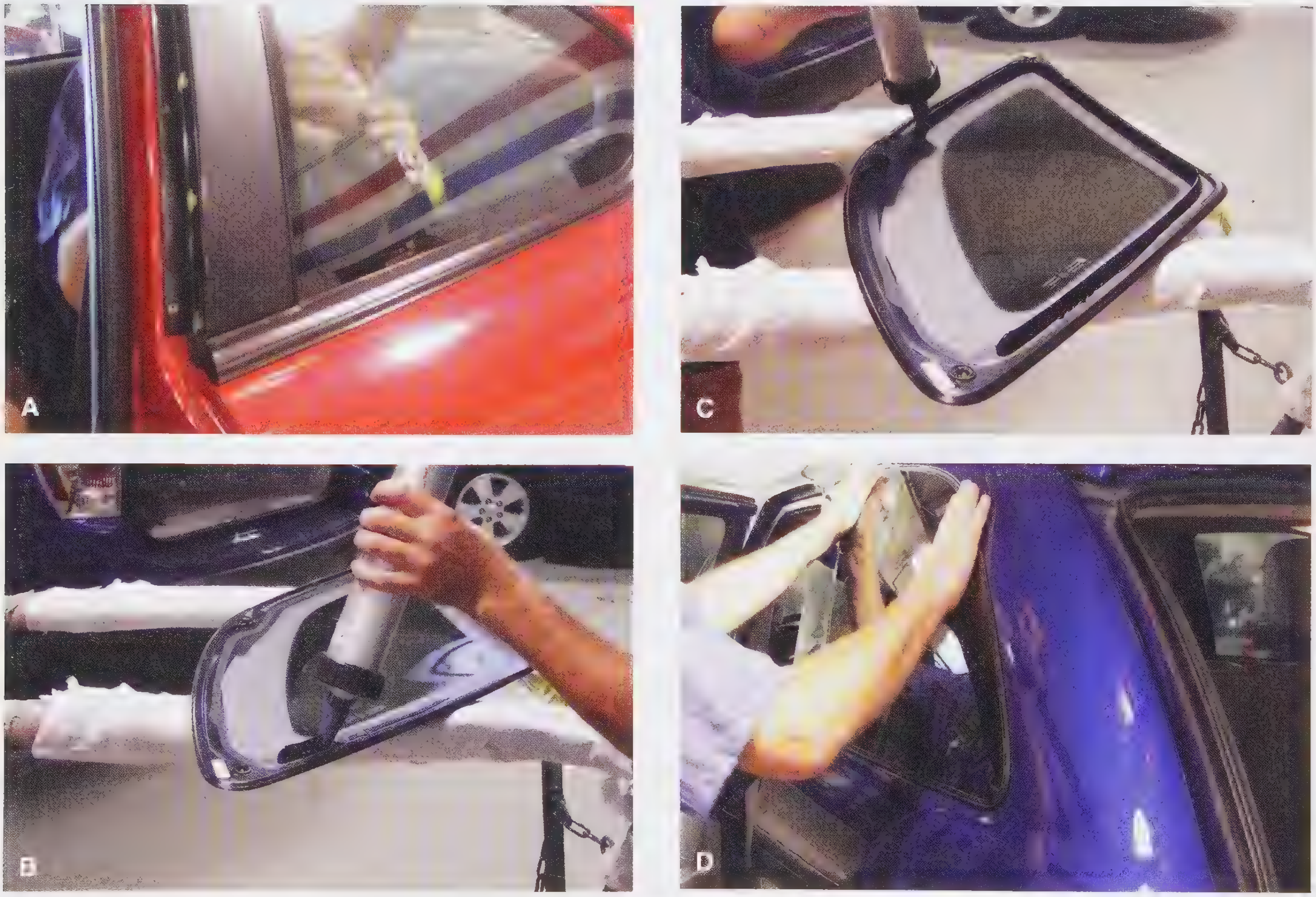


Figure 12-39. *A—The encapsulated glass is removed by cutting the urethane from inside the vehicle. B—A V-shaped bead of urethane is applied to the trimmed urethane on the glass. C—The entire perimeter is coated with a bead of urethane. D—The encapsulated glass is installed in the window opening.*

Summary

- Safety glass is designed to minimize the chances of injury if it is broken.
- Laminated safety glass consists of two layers of glass with a layer of polyvinyl butyl plastic between them. When this type of glass breaks, the glass shards cling to the plastic rather than being thrown about the inside of the vehicle.
- Tempered safety glass is a single layer of glass that has been heated, or tempered, during manufacture. The tempering process gives the tempered glass increased strength.
- Encapsulated glass has a plastic frame that is molded around a piece of safety glass. The glass cannot be separated from the plastic frame.
- Movable glass can roll up and down, slide backward and forward, or swing in and out.
- There are three types of fixed glass: bolted glass, rubber-set glass, and urethane-set glass.
- A hook tool is used to remove the locking strip on rubber-set glass. It can also be used to break the seal between the glass and the gasket.
- A plastic paddle, or bone, can also be used to break the seal between the glass and the gasket. Because the paddle is plastic, it will not scratch surfaces.
- A cut-out knife is inserted from outside the vehicle into the urethane holding a window in place.
- A windshield wire tool consists of two handles and a connecting wire. To use this tool, the wire is inserted through the urethane.
- There are a variety of glass repair materials on the market. Use only one manufacturer's products on any given job. Materials from different manufacturers may not be compatible.
- Glass primer is applied to glass to ensure a strong bond between the glass and the adhesive, and to block UV light.
- Damming tape is used to form a barrier to prevent urethane from squeezing out from under the glass.
- One-part urethane cures by reacting with the moisture in the air.
- Two-part urethane cures through a chemical reaction.
- Cured urethane has high lap shear strength. Lap shear strength is the amount of force required to break the urethane.
- If a window is secured with rivets, use a center punch to knock out the mandrels. Then drill out the rivets.
- Hinged glass is often attached with plastic screws.
- Rubber-set glass should be removed as a unit. However, if the gasket will not be reused, it can be cut out with a knife.
- Rubber-set glass with a locking strip can be removed by cutting out the gasket or by removing the glass from the gasket.
- In the full cut-out method of replacing urethane-set glass, the urethane layer between the glass and the pinch weld is cut and the windshield or back glass is removed. Then the urethane remaining on the pinch weld is cut so that only 1/16" (1–2 mm) remains.
- In the partial cut-out method of urethane-set glass replacement, the urethane is cut close to the glass so that most of the urethane remains on the pinch weld.
- There are three methods of leak detection: water, air, and ultrasonic.

Review Questions

Please do not write in this textbook. Place your answers on a separate sheet of paper.

1. All windshields are made out of laminated safety glass. True or False?
2. Define the term *laminated safety glass.*
3. The pattern in which tempered safety glass breaks is called ______.
4. Privacy glass is used to make windshields. True or False?
5. What type of glass has a plastic frame molded around it?
6. The up-and-down movement of rolling glass is controlled by a(n) ______.
7. ______ glass is the movable glass in the back window of a pickup truck cab.
8. A(n) ______-set windshield may have a locking strip.
9. A(n) ______ can be used to break the seal between the glass and the gasket without scratching the paint.
10. A power caulking gun produces a more uniform band of urethane than a hand caulking gun. True or False?
11. Explain the difference between an oscillating knife and a reciprocating knife.
12. Always use silicone spray as a lubricant when installing a rubber-set windshield. True or False?
13. ______ is used to form a strong bond between the glass and the adhesive and to block UV light.
14. What should be put on bare metal in the pinch weld area before installing glass?
15. Damming tape is used to adhere a urethane-set windshield to the pinch weld. True or False?
16. ______ tape has a lap shear strength of 10–15 PSI.
17. The ______ the temperature, the faster urethane cures.
18. When performing the full cut-out method of urethane-set glass replacement, the urethane remaining on the pinch weld is cut so that ______" remains.
19. Explain how to cut the nozzle of the tube of urethane to stack up the urethane.
20. Name three methods for leak testing a windshield.

ASE-Style Questions

1. Technician A says that laminated safety glass consists of two layers of glass with a layer of plastic between them. Technician B says that windshields are made of laminated safety glass. Who is right?
   (A) A only.
   (B) B only.
   (C) Both A and B.
   (D) Neither A nor B.
2. Technician A says tempered glass brakes into small cube-shaped pieces. Technician B says that tempered glass is weaker than conventional glass. Who is right?
   (A) A only.
   (B) B only.
   (C) Both A and B.
   (D) Neither A nor B.
3. Technician A says the run channel on a sedan door is inside the door only. Technician B says run channels are lined with felt or rubber. Who is right?
   (A) A only.
   (B) B only.
   (C) Both A and B.
   (D) Neither A nor B.
4. Which of the following is fixed glass?
   (A) Sliding.
   (B) Hinged.
   (C) Urethane-set.
   (D) Turning.
5. Moldings around the outside of a windshield are called ______ moldings.
6. Technician A says a cut-out knife is used from outside the vehicle. Technician B says a banana knife is used from outside the vehicle. Who is right?
   (A) A only.
   (B) B only.
   (C) Both A and B.
   (D) Neither A nor B.
7. Glass cleaner should not contain ______.
   (A) petroleum
   (B) silicone
   (C) excessive amount of ammonia
   (D) All of the above.
8. One-part urethane cures by ______.
   (A) chemical reaction
   (B) reacting with moisture from the air
   (C) UV light
   (D) All of the above.
9. Technician A says that urethane cure time is dependent on the type of urethane. Technician B says that urethane cure time is dependent on cure temperature. Who is right?
   (A) A only.
   (B) B only.
   (C) Both A and B.
   (D) Neither A nor B.
10. Window rivets need to be drilled out. Technician A wants to use a drill bit slightly smaller than the hole in the rivet. Technician B wants to knock the mandrel out of the rivet first. Who is right?
    (A) A only.
    (B) B only.
    (C) Both A and B.
    (D) Neither A nor B.
11. A door glass with a retainer needs to be installed. Technician A wants to pull back on the glass to set the retainer in the run channel. Technician B says that the glass must be pushed at an angle to set the retainer. Who is right?
    (A) A only.
    (B) B only.
    (C) Both A and B.
    (D) Neither A nor B.
12. A rubber-set back glass needs to be removed. The gasket will not be reused. Technician A says the gasket and glass must be removed as a unit. Technician B wants to cut the gasket. Who is right?
    (A) A only.
    (B) B only.
    (C) Both A and B.
    (D) Neither A nor B.
13. All of the following are steps in installing a rubber-set windshield, EXCEPT:
    (A) installing a rope.
    (B) setting a gasket in place on a pinch weld.
    (C) pulling on the rope.
    (D) applying urethane to a pinch weld.
14. A rubber-set glass with a locking strip must be removed. Technician A wants to start in the corner with the smallest radius. Technician B wants to start in the corner with the largest radius. Who is right?
    (A) A only.
    (B) B only.
    (C) Both A and B.
    (D) Neither A nor B.
15. Technician A thinks that the partial cut-out method is the preferred way to replace a urethane-set windshield. Technician B thinks that the full cut-out method is the preferred way. Who is right?
    (A) A only.
    (B) B only.
    (C) Both A and B.
    (D) Neither A nor B.

16. A urethane-set windshield is test fit before installation. Technician A wants to position the windshield on setting blocks. Technician B wants to mark the proper windshield position with masking tape. Who is right?
    (A) A only.
    (B) B only.
    (C) Both A and B.
    (D) Neither A nor B.
17. When replacing a urethane-set windshield, Technician A applies glass primer to bare metal areas. Technician B applies glass primer to exposed paint areas. Who is right?
    (A) A only.
    (B) B only.
    (C) Both A and B.
    (D) Neither A nor B.
18. A urethane-set glass is set in place on the urethane. Technician A says that the glass cannot be lifted from the urethane once it contacts the adhesive. Technician B says that hand pressure should be used to set the glass into the urethane. Who is right?
    (A) A only.
    (B) B only.
    (C) Both A and B.
    (D) Neither A nor B.
19. An encapsulated quarter glass needs to be removed. Technician A wants to work from outside the vehicle. Technician B wants to work from inside the vehicle. Who is right?
    (A) A only.
    (B) B only.
    (C) Both A and B.
    (D) Neither A nor B.
20. Which of the following leak tests uses bubbles in soapy water to find leaks?
    (A) Water.
    (B) Air.
    (C) Oil.
    (D) Ultrasonic.

Section 3

Structural Repairs

Chapter 13. Unibody/Frame Straightening Equipment
Chapter 14. Measurements
Chapter 15. Unibody Straightening
Chapter 16. Full Frame Repair
Chapter 17. Structural Panel Replacement

Chapter 13

Unibody/Frame Straightening Equipment

Objectives

After studying this chapter, you will be able to:

- Identify and explain how to use hook-up equipment.
- Identify and explain how to use tie-down equipment.
- List the types of pulls.
- Identify various types of frame machines.

Technical Terms

basket-style pull
bench/rack system
blocking
claw hook
double grab hook
floor pot system
floor rail system
flyback
frame bench
frame rack
frame wraps
full-frame clamps
grab hook
hookups
hydraulic rams
portable system
pull
pull hooks
pull plates
pulling chain
rotating-pull clamp
safety chain
sandwich clamp
self-tightening clamp
slings
slip hook
swing arm pulls
tie-down clamps
tie-down hook
tie-downs
tower pull
two-rail portable system
vector pull
wedge clamp

Introduction

This chapter introduces unibody and full-frame straightening equipment. There is a variety of straightening equipment available. The use of this equipment requires careful planning. Straightening a unibody or full frame also requires the use of considerable force. All straightening equipment must be able to withstand the force required to straighten structural parts. Never use light-duty equipment when making structural repairs.

Pulling Equipment

Hydraulic equipment, such as jacks and rams, are rated by lifting capacity. The lifting capacity is measured in tons. For example a 2 1/2-ton floor jack can safely raise a vehicle with a weight of up to 5,000 pounds. Similarly a 10-ton hydraulic ram can raise a 20,000 pound vehicle. The capacity of most rams used in structural repair is 10 tons. All equipment used in structural repair, such as chains, hooks, clamps, etc., must be able to withstand 10 tons of pulling force.

Pulling Chain

Pulling chain is made from heat-treated alloy steel and has a minimum tensile strength of 25,000 pounds. A 3/8" chain is used to pull damaged structural components into alignment. A 1/4" chain, which has a lower tensile strength than 3/8" chain, can also be used to pull structural damage as long as the chain is double wrapped.

One end of the chain is attached to the damaged vehicle. The other end is attached to a hydraulic ram. As the ram moves, the chain tightens and pulls on the damage. As the chain pulls, it moves the damaged structural part back to its original position. Pulling chain is also used to tie down vehicles.

While in use, the chain is pulled so tight that it would fly back violently toward the ram if it were to break or come loose from its attachment. This is known as ***flyback***. The flying chain could easily injure or kill someone in its path. To prevent this type of accident, use a safety chain or a chain wrap. A ***safety chain*** is a supplemental chain or cable that is connected to the pull chain. A welding blanket is commonly used as a chain wrap. See **Figure 13-1**.

Never heat a chain. Heat will weaken the links. Avoid twists in the chain. When the chain is installed, arrange it so the links are in line as shown in **Figure 13-2**. Never stand between the point where the chain is hooked up to the vehicle and the ram or directly in line with the chain when the chain is tight.

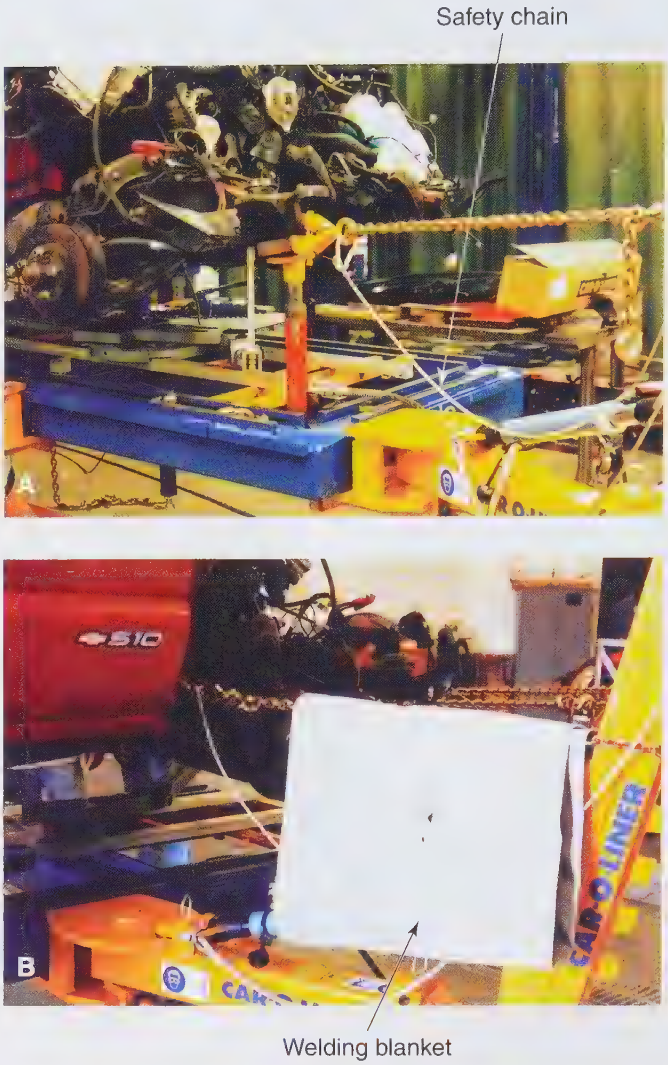


Figure 13-1. *A—The safety chain prevents flyback if the chain breaks or the hookup fails. B—A welding blanket can also be used to prevent flyback. The weight of the blanket causes the chain to drop to the floor.*

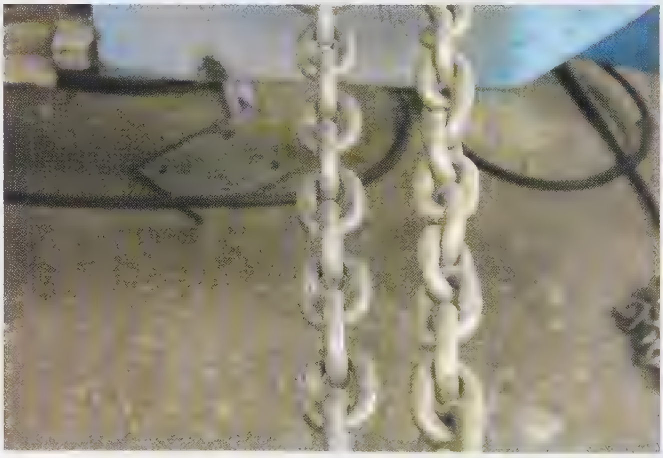


Figure 13-2. *The chain on the right is twisted and the chain on the left is straight. The straight arrangement of the links will make a straight pull.*

Chains should be inspected before use. If a link has a nick or a gouge, the chain should not be used. **Figure 13-3** shows a chain that has been stressed in excess of its capacity. The chain links no longer have the original oval shape. The oval shape is distorted because the links have stretched. Never use a chain that has galling or a non-oval link.

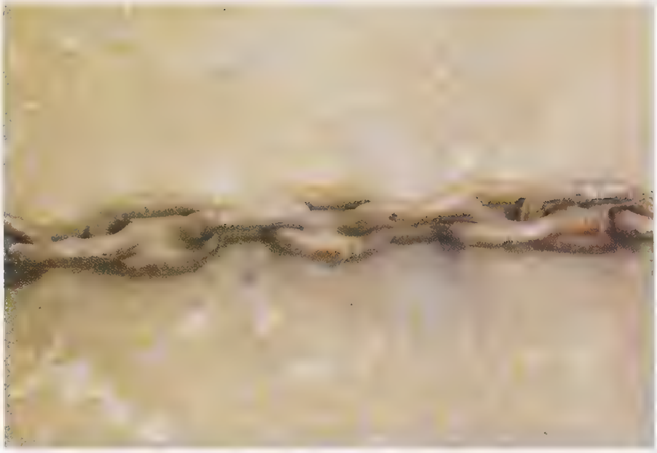


Figure 13-3. *The links of this chain have been distorted. The chain has been overstressed, causing galling.*

Chain Hooks

The three types of chain hooks used in collision repair are the slip hook, the grab hook, and the claw hook. The ***slip hook*** is used to attach a chain to a clamp or a chain loop. The ***grab hook*** and ***claw hook*** attach chains to other chains. See **Figure 13-4**. All the hooks are attached to a chain with a clevis pin. A ***double grab hook*** can be used to tie two chains together or to shorten a length of chain. A double grab hook can be

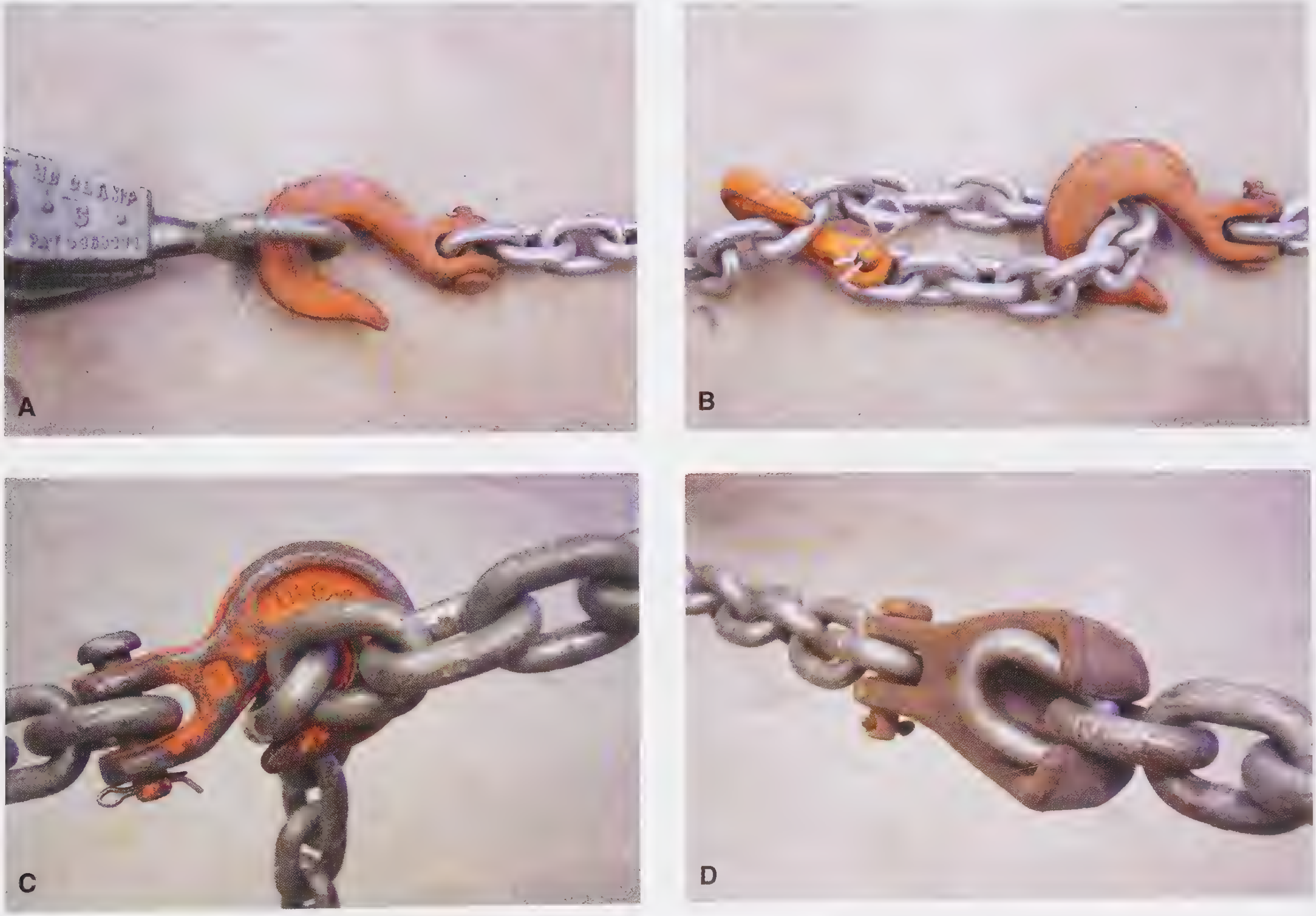


Figure 13-4. *A—This slip hook is attached to a chain and clamp. B—This slip hook connects a chain to a loop in another chain. C—The grab hook attaches to the last link on one chain and fits over a link on another chain, connecting the two chains together. D—A claw hook connects two chains by attaching to the end of one chain and wrapping around a link on another chain.*

assembled from an alloy connecting ring and two grab hooks or purchased as a dedicated unit as shown in **Figure 13-5**.

Tie-Downs

Tie-downs are used to hold the damaged vehicle in place so that pulls can be made to align the damage. When the tie-downs positioned in an undamaged area of the vehicle, they prevent flexing and deformation of the undamaged area during pulls. When tie-downs are positioned in a damaged area, they can be used to correct the damage along with the pulls. The tie-downs must be stronger than the pull or the damage. If the tie-downs are not stronger than the pull or the damage, they will break loose during the pull, resulting in possible injury to the technician and certain damage to the vehicle. In most cases, tie-downs are made in the center section of the vehicle.

Full-Frame Tie-Downs

Frame wraps can be used to tie-down a full-frame vehicle. **Figure 13-6** shows a simple frame wrap that consists of a chain looped around a frame and tied back to itself. This arrangement prevents movement in one direction only. The frame will move down during any pull except an upward pull, which will raise the frame. The downward movement will first load the suspension, causing the vehicle to look like it is carrying a heavy weight. As the pull continues, the suspension will be fully compressed. With the suspension fully compressed, the frame damage can be pulled out. However, loading the vehicle in this manner needlessly stresses the suspension and slows the pulling process.

Placing ***blocking*** under the frame prevents downward movement of the frame at the location of the blocking. The blocking supports the vehicle. The suspension is not stressed because it does not move down. Blocking also sets the height of the vehicle during the pull. Properly placed blocking will help correct damage during the pull.

Figure 13-7 shows a jack stand positioned as blocking near the frame wrap. Hardwood blocks can also be used as blocking. A large surface area is desirable for blocking. The large surface area will spread out the force on the frame and minimize distortion. If bolt heads protrude from the bottom of the frame rail, drill holes in the wood block so the bolt heads rest in the holes and the frame rail contacts the block. **Figure 13-8** shows a block that has been drilled.

Wrapping the frame can lead to damage of the frame flanges. As the chain loop tightens under the pressure of the pull, the flanges are forced together, permanently damaging them. To prevent this problem, the frame wrap can be positioned at a cross member. The strength of the cross member may prevent damage to the flanges. Another option is to fabricate small I-beams from 1/8" steel plates. These I-beams can be placed between the flanges to prevent collapse.

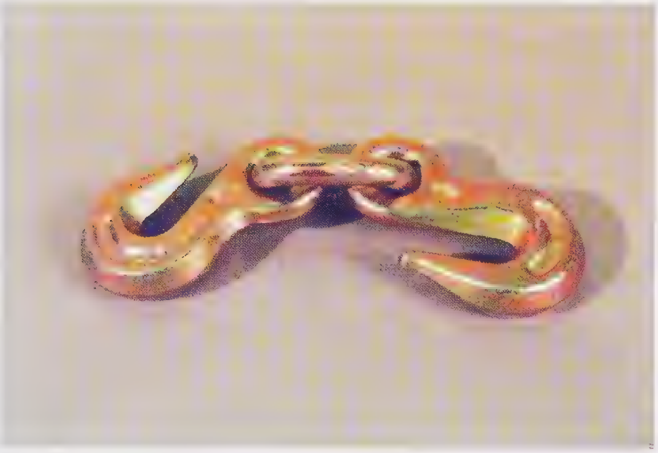


Figure 13-5. *A double grab hook can be used to shorten a length of chain or to tie two lengths of chain together.*

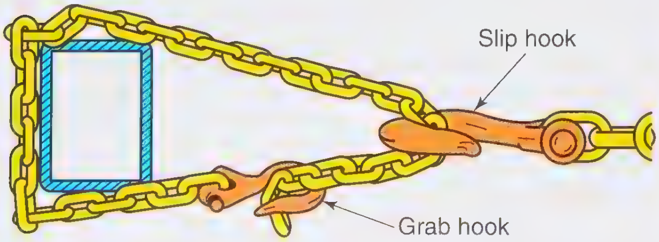


Figure 13-6. *A chain is wrapped around a full frame. The grab hook is attached to the chain, forming a loop. A slip hook connects the loop to the pull chain.*

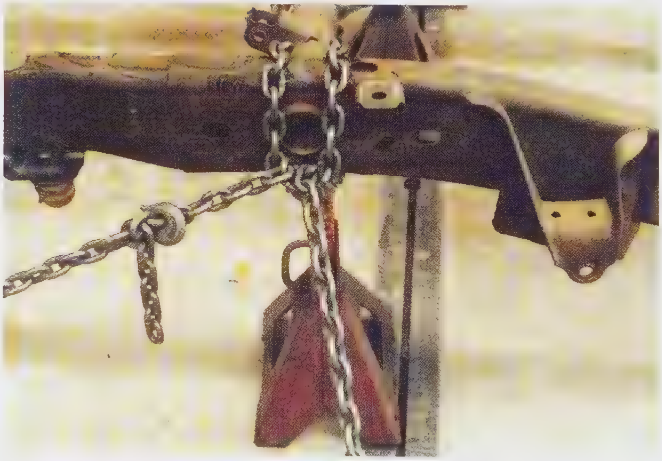


Figure 13-7. *A jack stand serves as blocking to support the frame at the tie-down. Frames will move down during any pull except an upward pull.*

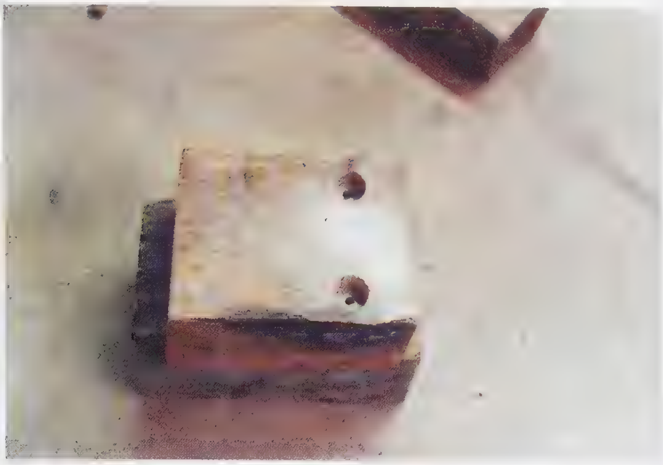


Figure 13-8. *This hardwood block is used to support a full frame. The holes in the block allow clearance for bolt heads or rivets in the frame.*

The more complex frame wrap shown in **Figure 13-9** prevents both forward and sideways movement. The blocking prevents downward movement. The frame wrap at the blocking also prevents upward movement. There is still the problem of flange collapse with this type of tie-down.

A 3/8" chain should be used to make tie-downs. It can be difficult to feed a chain of this size between the body and the frame. Parts, such as the gas tank, may need to be loosened and raised or lowered to allow the chain through. Avoid placing chains where they can contact and damage brake lines or hoses, gas lines, or electrical wires.

Another way to tie down a full-frame vehicle is to use a ***tie-down hook***. See **Figure 13-10**. Full-frame vehicles often have holes or slots on the underside of the frame. A tie-down hook is slipped inside one of these holes. This prevents movement in one direction. A hook may also be placed in the corner where the frame rail and a cross member meet. Blocking not only prevents downward movement, but it will lock the hook in place.

The last way to tie down a full-frame vehicle is with ***full-frame clamps***. These clamps are placed on the frame at predetermined locations. They prevent movement in all directions except up and do not cause the frame flanges to collapse. The full-frame clamp shown

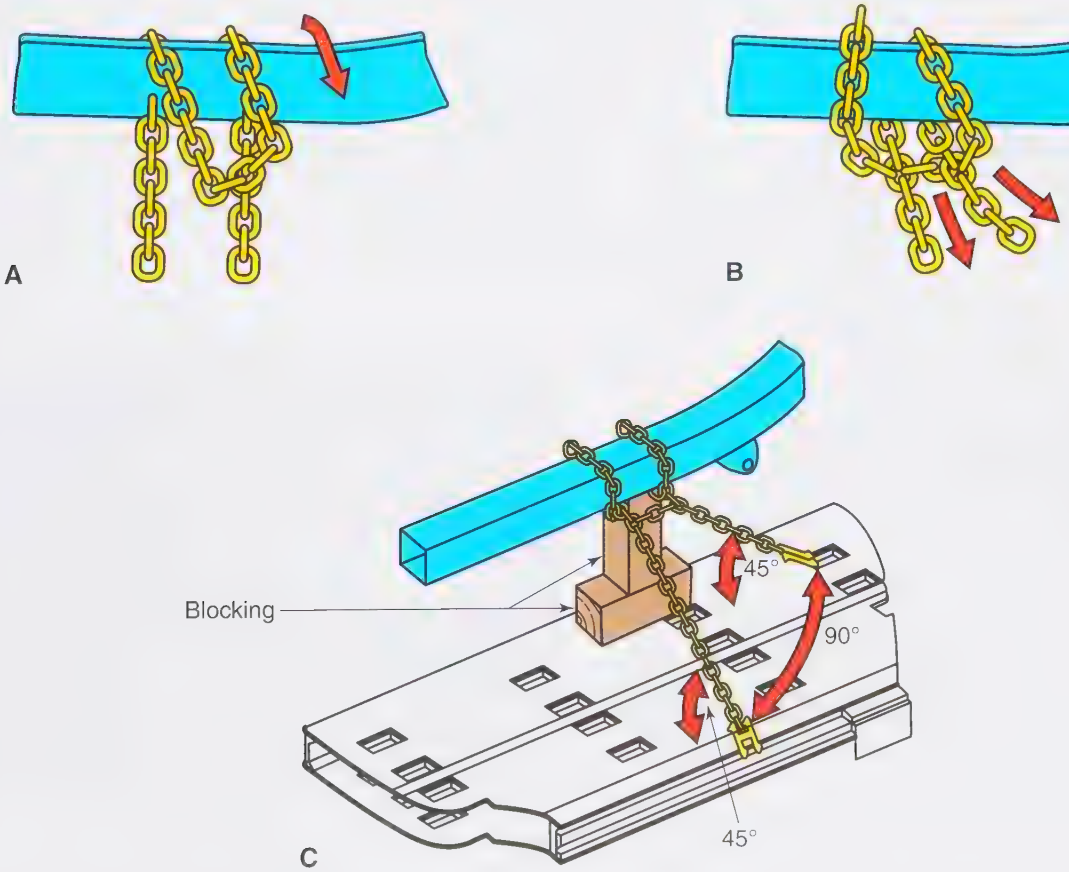


Figure 13-9. *The frame wrap tie-down prevents forward and sideways movement to the right, as well as upward and downward movement. The procedure for making this frame wrap is as follows. A—Make a loop with the chain. B—Slip both ends of the chain through the loop. C—Tie down the ends of the chain. (Chief Automotive Systems)*

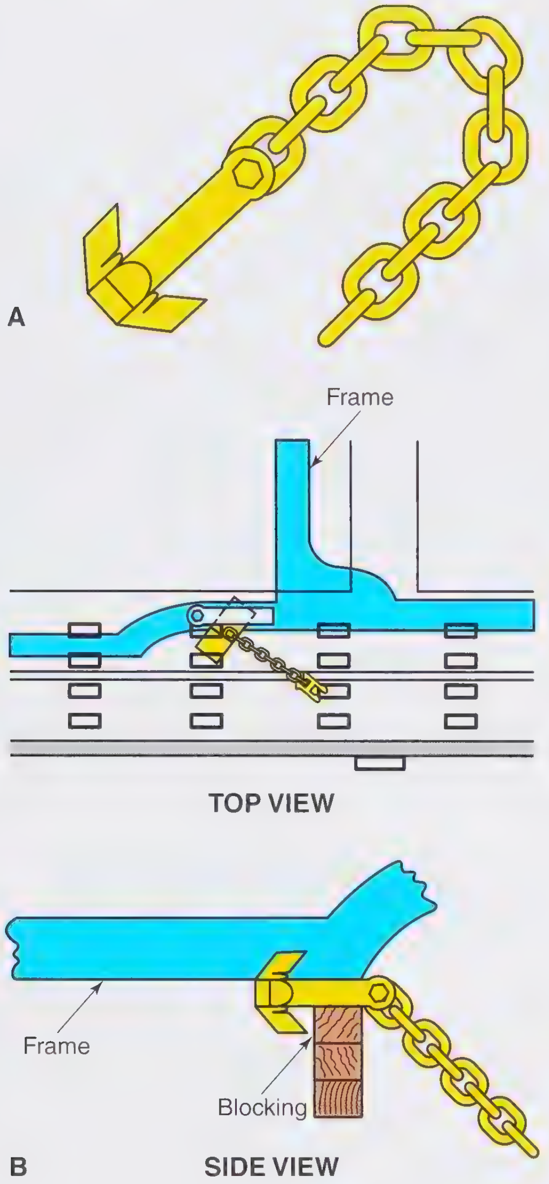


Figure 13-10. *A—Tie-down hook. B—The tie-down hook is inserted into a hole in the frame. Blocking not only sets vehicle height, but it keeps the hook in place. (Chief Automotive Systems)*

in **Figure 13-11** is placed on the rear spring front mount. Other clamps are designed to hold an open or closed C-channel frame or a box frame. The clamps always grab the bottom portion of the rail. The positioning of the full-frame clamps may be specified by instructions included with the clamps.

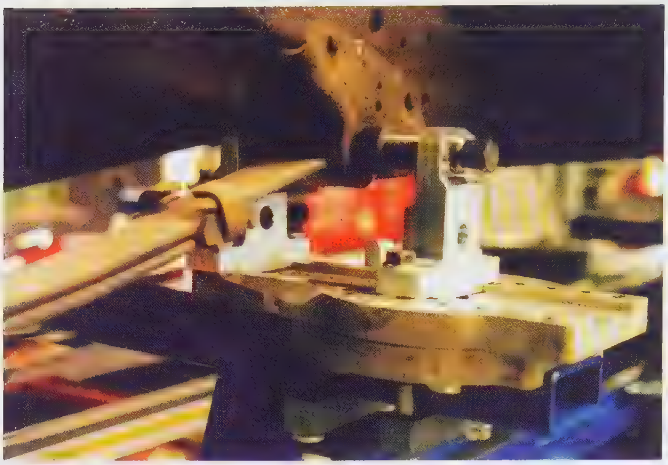


Figure 13-11. *This full-frame clamp is attached to the rear spring mount. Other clamp locations use the lower portion of the frame.*

Unibody Tie-Downs

Most unibody vehicles are tied down with clamps that connect to the pinch weld flanges in the rocker panels. The ***tie-down clamps*** are placed at the corners of the vehicle's center section. When properly connected to the floor or the frame machine, the four corner unibody tie-down clamps will prevent movement in any direction. A unibody clamp is shown in **Figure 13-12**.

There are variations in appearance among clamps from different manufacturers, but they all have the same basic parts. The clamp teeth must be kept clean so they can bite into the pinch weld flange. Clean out undercoating from the teeth with a wire brush. The clamp bolts and nuts should be inspected before each use. Damaged bolts and nuts should be replaced. Use grade-8 bolts and nuts when making replacements.

The clamps should be positioned at each corner of the unibody in an area on the pinch weld flange

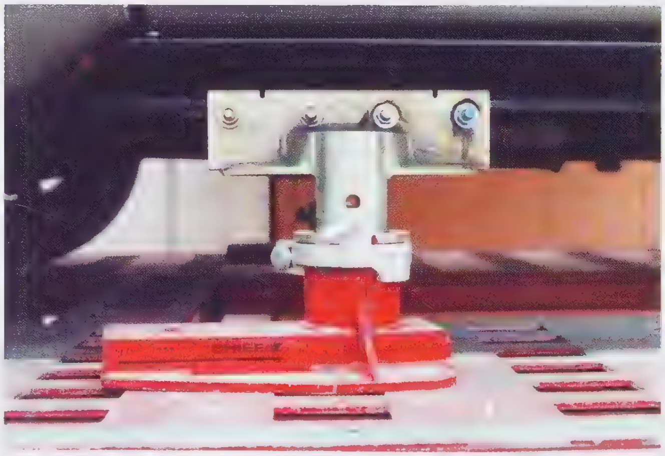


Figure 13-12. *A unibody vehicle is tied down by rocker panel pinch weld clamps placed at the four corners of the center section. The height of the unibody clamps is adjustable. Tightening the upper four bolts makes the clamp bite into the pinch weld.*

that does not have gas lines, brake lines, or electrical wires running on the back side of it. The clamp must be level in relation to the bottom of the rocker panel. If the clamp is not level, the higher end of the clamp may dent the rocker panel as the pull forces the vehicle down. Once the clamp is positioned, tighten the nuts with an impact wrench. A few unibody vehicles do not have pinch weld flanges on the rocker panels. Special fixtures have been designed to hold these types of vehicles. Other vehicles may have pinch welds that point outward rather than downward. There are special adapters available to tie these types of vehicles down. See **Figure 13-13**.

Hookups

Hookups are used to attach the pull to the damage. As with tie-downs, hookups must be stronger than the pull or the damage. A weak hookup can break under the force of the pull. A broken hookup can fly back, like a broken chain. A weak hookup can result from improper clamping (the nuts on a clamp are not tight), slipping (a frame hook slides out), or clamping to a weak part of the vehicle, such as a thin sheet metal component. In some cases, a vehicle part, such as a torn apron, is weakened by damage. Hookups should be made at the strongest area available. Look for an area that is two or three layers of metal in thickness. Multiple hookups will spread the pull force. Use as many hookups as possible. There is a wide variety of hookup equipment available.

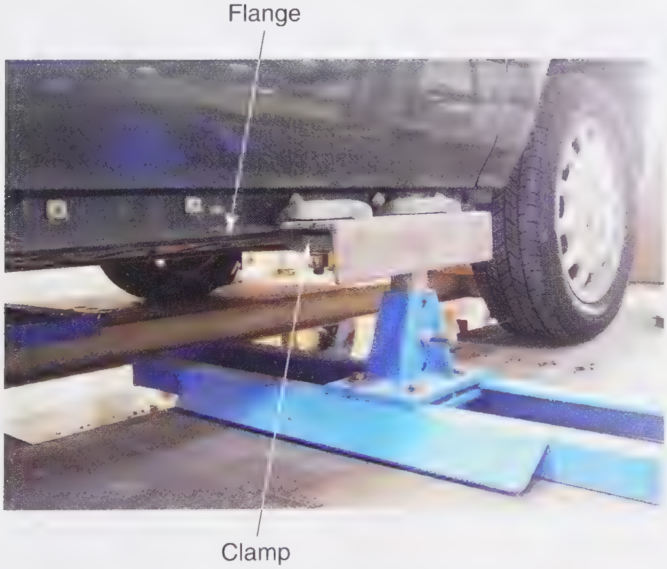


Figure 13-13. *The pinch welds on this vehicle point outward. A special clamp is used to hold this type of pinch weld.*

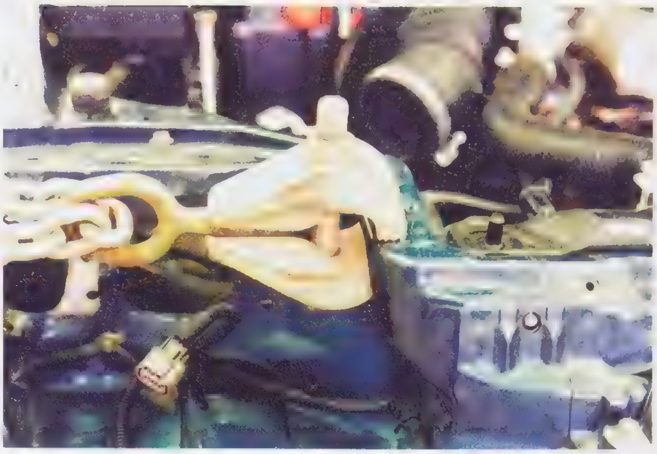


Figure 13-14. *Pulling on the ring causes the wedge clamp to bite into the metal.*

Clamps

A ***wedge clamp*** is shown in **Figure 13-14**. After positioning the clamp on the vehicle, tighten the nut so the clamp's teeth bite into the metal. As the clamp is pulled, the wedge forces the clamp tighter. Wedge clamps are available in several sizes. A clamp with relatively wide jaws spreads the force of the pull over a larger area, decreasing the likelihood that the metal will break during the pull. A deep jaw clamp can reach around a flange that a shallow jaw clamp would otherwise collapse. **Figure 13-15** shows various wedge clamps. Clamps may also have a flange that allows pulls in two directions. **Figure 13-16** shows a two-direction clamp. When using a wedge clamp on the frame of a

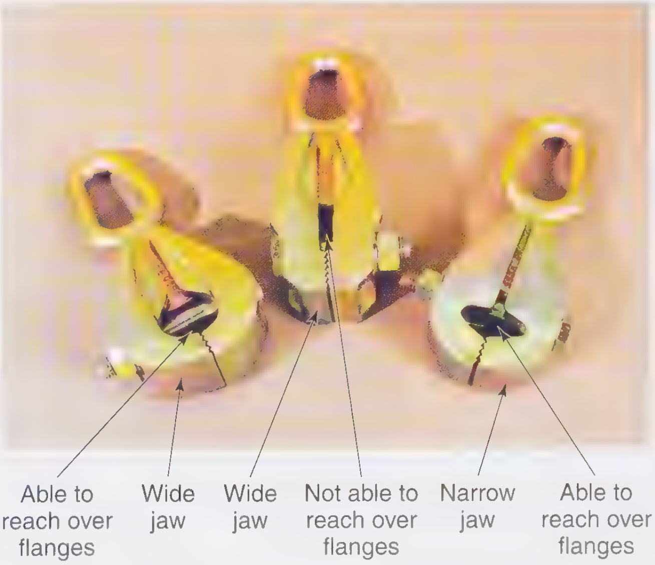

Able to reach over flanges
Wide jaw
Wide jaw
Not able to reach over flanges
Narrow jaw
Able to reach over flanges

Figure 13-15. *Wedge clamps are available in a variety of shapes.*

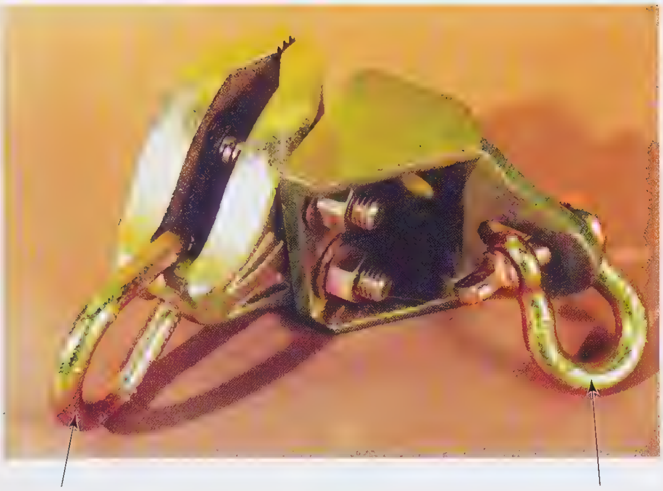


Figure 13-16. *This clamp can be used to pull in two directions.*

full-frame vehicle, a MIG weld bead can be made across the frame rail to prevent the clamp from slipping.

A ***rotating-pull clamp*** can be used to pull at many different angles, which the wedge clamp cannot do. See **Figure 13-17**. This clamp does not self-tighten like a wedge clamp. It is especially important that the teeth on this type of clamp be kept clean. On all clamps, the nut and bolt should be inspected and replaced if damaged. See **Figure 13-18**.

A ***sandwich clamp*** is shown in **Figure 13-19**. This type of clamp is used to repair a damaged unirail. The lower part of the sandwich clamp is inserted inside a damaged unirail. A hole is drilled in the unirail. The upper part of the clamp is placed on the outside of the rail. The upper and lower parts are bolted together through the hole. This clamp can be positioned at a buckle.

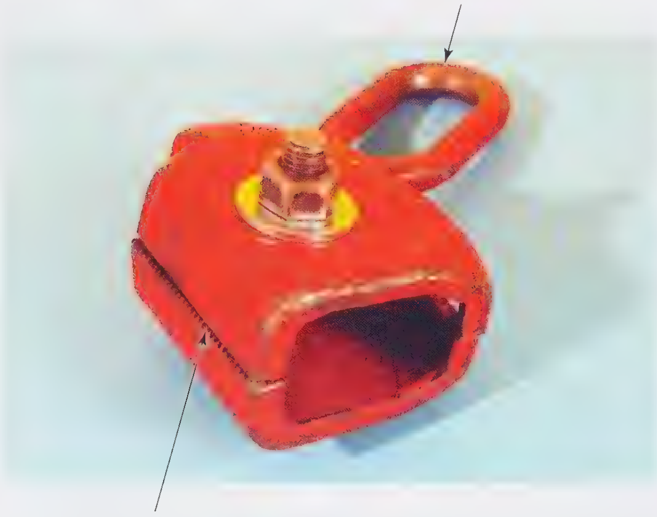


Figure 13-17. *This rotating pull clamp can pull at many different angles.*

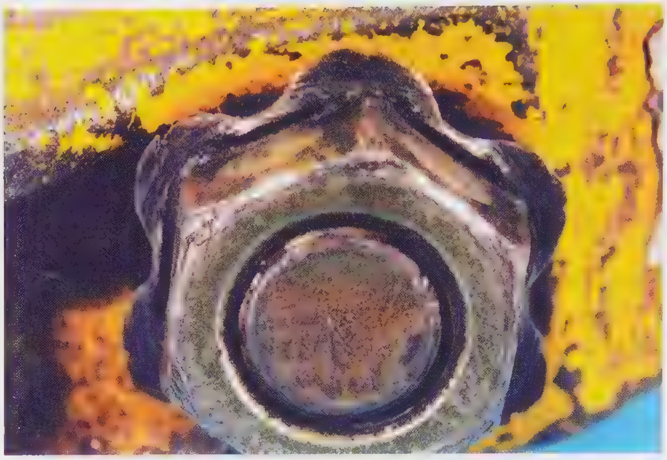


Figure 13-18. *The nut on this clamp has been damaged by overtightening. Do not use a clamp with damaged nuts or bolts.*

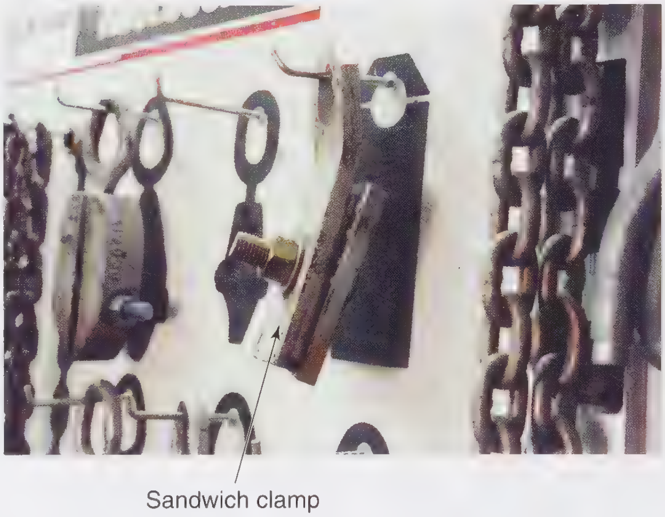


Figure 13-19. *This clamp can be used to pull a unirail. The straight portion of the clamp is inserted inside the rail, a hole is drilled in the unirail and the angled portion of the clamp is bolted in place. The pull is made from the angled portion.*

A ***self-tightening clamp***, **Figure 13-20,** is placed inside the open end of a unirail. As the clamp is pulled, it expands and holds onto the unirail. There are several variations of this clamp to fit different vehicles. Regular clamps will not reach around the flanges at the end of a unirail.

Pull Plates

Pull plates are designed to be attached to a vehicle with bolts. Use at least two bolts to hold the plate in place. The plate has enough holes in it to allow many

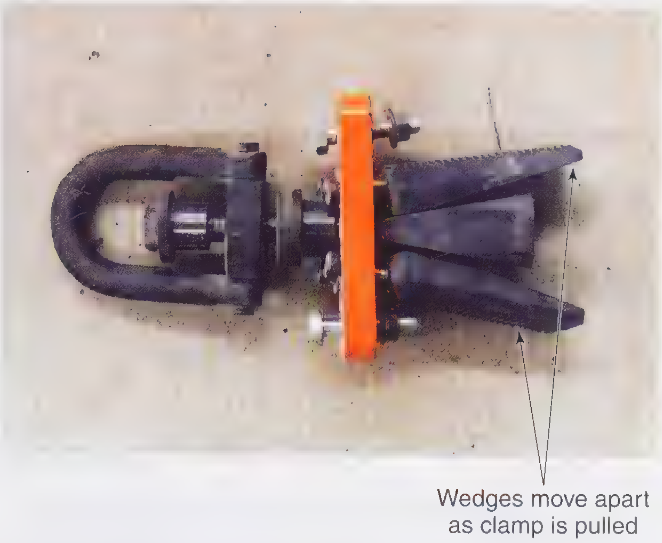


Figure 13-20. *This clamp is inserted into the end of a unirail. Pulling on the clamp causes the wedges to grab the sides of the unirail.*

different bolt combinations. See **Figure 13-21**. A slip hook is attached to the plate for pulling. The pull plate should be attached to the frame with grade-8 bolts. A pull plate used to align a McPherson strut tower is shown in **Figure 13-22**. This plate is bolted to the strut tower in place of the strut. A slip hook is attached to the top of the puller. The tower can be moved forward or sideways with this plate. The pull plate shown in **Figure 13-23** is bolted to the lower frame rail and the engine cradle. This allows the rail and the cradle to be aligned at the same time.

Pull Hooks

Pull hooks are designed to reach around an obstruction and push against the back side of the damage.

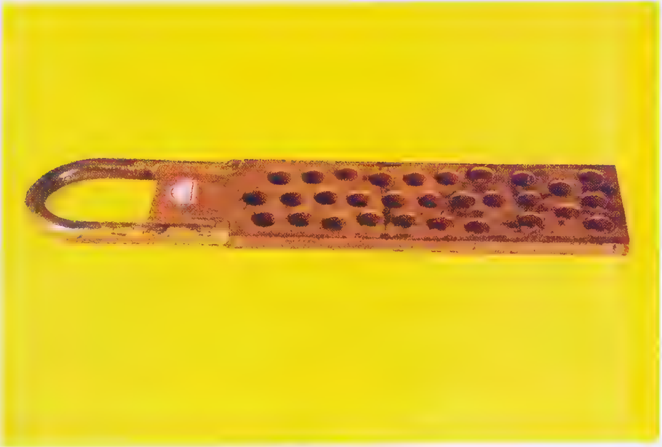


Figure 13-21. *Use at least two grade-8 bolts to hold a pull plate in place.*

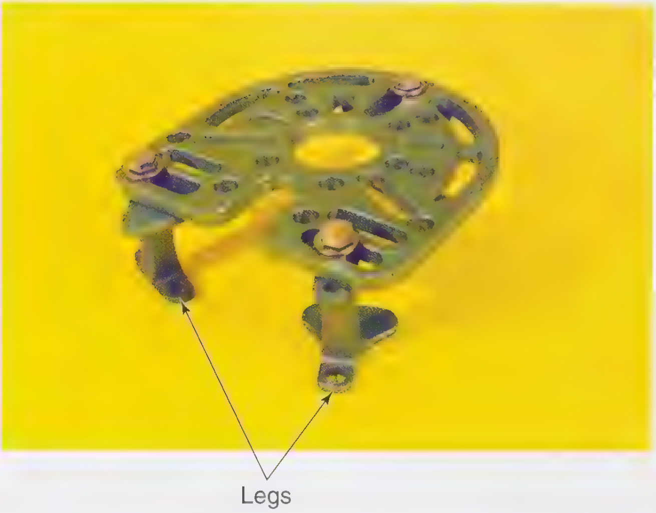


Figure 13-22. *The legs of this puller are attached to the shock tower bolt holes. The pull is made from the top of the clamp.*

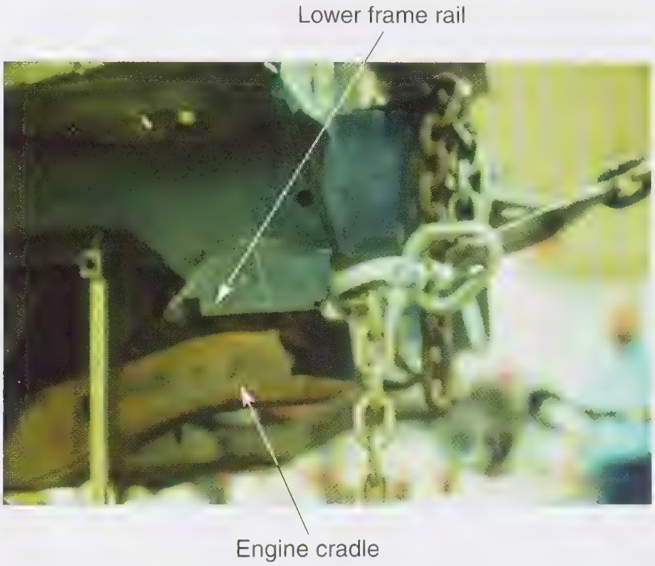


Figure 13-23. *A pull plate is bolted between the engine cradle and the radiator support. Pulling on the plate moves the cradle and the support at the same time.*

Figure 13-24 shows a pull hook. Hooks have removable pull plates that can be used to spread the force of the pull over a larger area. A larger surface area is less likely to tear or stretch metal.

Notice that there are two holes in the hook handle. The pull chain should be hooked in the hole that allows the pull to be perpendicular to the pushing surface. See **Figure 13-25**. A pull that is not perpendicular to the pushing surface is not stable. The hook is held in place only by friction and the pulling force. A misaligned pull will make the hook slip.

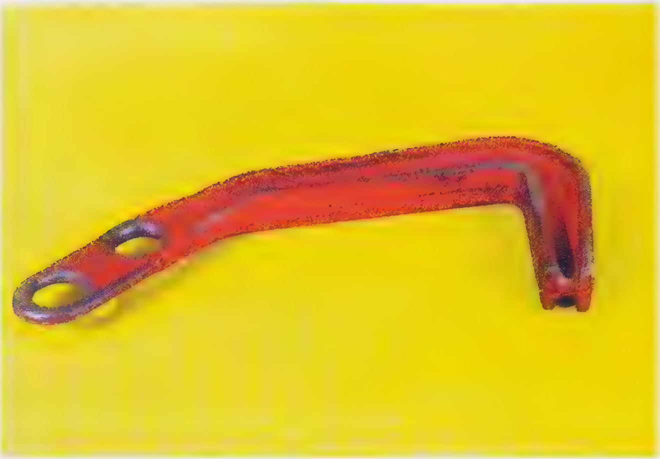


Figure 13-24. *This hook has two holes for a chain or slip hook.*

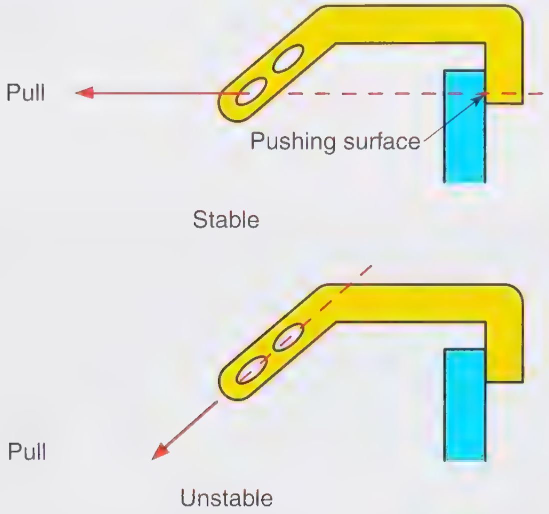


Figure 13-25. *The pull direction should be perpendicular to the push surface. Misalignment makes the pull unstable.*

On unibodies, a frame hook can be used on the rear body panel, center pillar, radiator support, and the front frame rails. On full-frame vehicles, a wood block can be placed inside the frame flanges to prevent collapse.

Slings

Slings are wrapped around damaged rails or pillars. Slings may be made out of steel cable or nylon. See **Figure 13-26**. A slip hook is placed through the sling hooks for pulling.

A sling will tighten as it is pulled. This may collapse flanges or unibody box members, such as a center pillar. To prevent collapse, a steel bar or a block of wood that is slightly wider than the box member is positioned between the sling and the box member. See **Figure 13-27**. The block does not allow the sling to tighten enough to damage the box member.

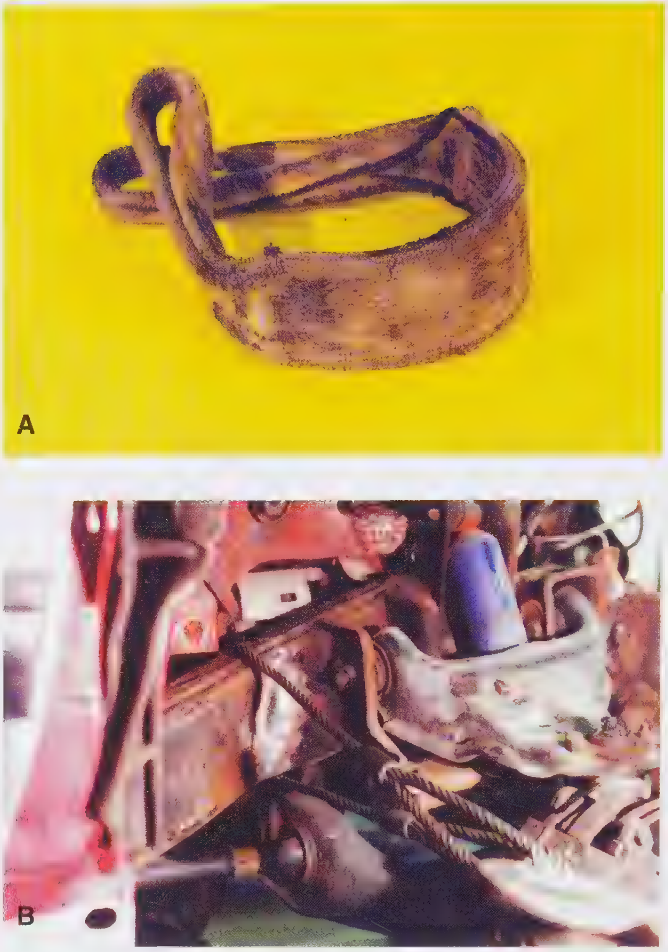


Figure 13-26. *Both the nylon sling and the steel cable sling are used to make quick hookups. A—Nylon sling. B—Steel cable.*

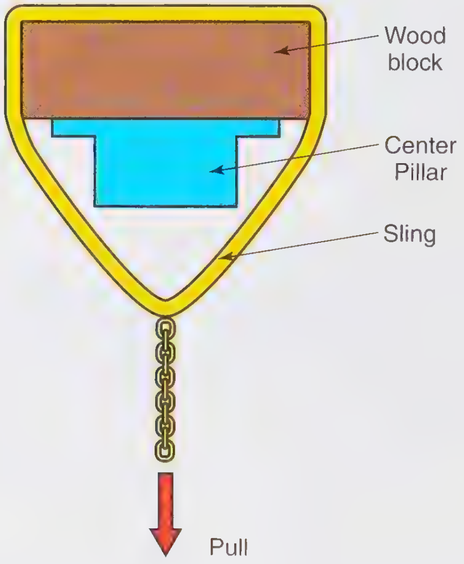


Figure 13-27. A *steel plate or wooden block placed behind the pillar keeps the sling from bending the flanges.*

Frame Wraps

In addition to being used as tie-downs, ***frame wraps*** can also be used to hook up to damaged full-frame vehicles and some unibodies. To make a frame wrap, simply wrap the chain around the frame and the use the chain to make the pull.

Position the frame wrap at a cross member to prevent the wrap from slipping forward or rearward during a pull. The loop for the frame wrap should be long. A long loop is less likely to twist under pressure. A ***basket-style pull*** involves wrapping a chain around the frame and tying the chain to itself. A second chain is attached to the basket for pulling. The longer the basket, the less likely the chain will twist. See **Figure 13-28**.

Hydraulic Rams

The four-ton ***hydraulic rams*** used in nonstructural repair are powered by hand-operated hydraulic pumps. The ten-ton hydraulic rams used in structural repair may be powered by a hand pump, but they are more commonly powered by an air-powered pump. See **Figure 13-29**. The pump is connected to the shop's compressed air line and to the ram. When the lever is pressed, air pressure drives the pump. With this setup, each ram has its own pump. Each pump is operated individually.

Some frame machines have a central hydraulic system. In this type of system, the technician only has to push a button and all the rams connected to the system will operate at the same time. Individual rams can be turned off as needed. The rams or the frame machine may be equipped with a gauge to indicate pulling pressure. When pulling pressure is applied, the technician can see how much force is being used.

A ten-ton hydraulic power set is shown in **Figure 13-30**. The set includes a ten-ton ram, hand pump, extensions, and various ends. A set such as this may be used in full-frame repair and also in unibody structural repair if a strong base is available. The area

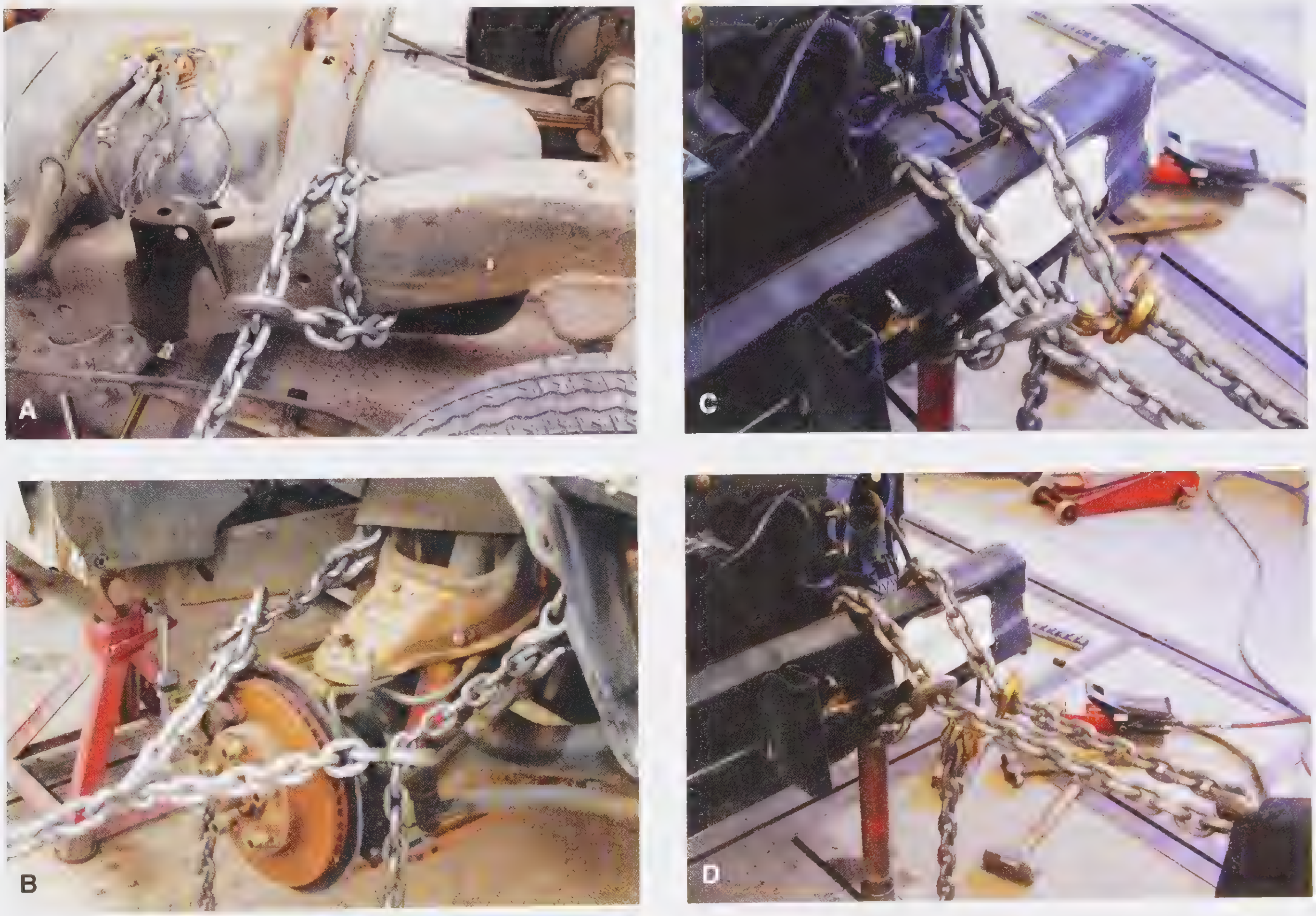


Figure 13-28. *A—The loop on this frame wrap is short, which may cause this side pull to twist. B—This is a basket pull. The chain is wrapped around the frame in the suspension mounting area. Notice the length of the basket. C—This is a basket pull on a unibody bumper reinforcement. The bumper reinforcement is welded to the lower frame rail. D—A long basket prevents twist during the pull.*

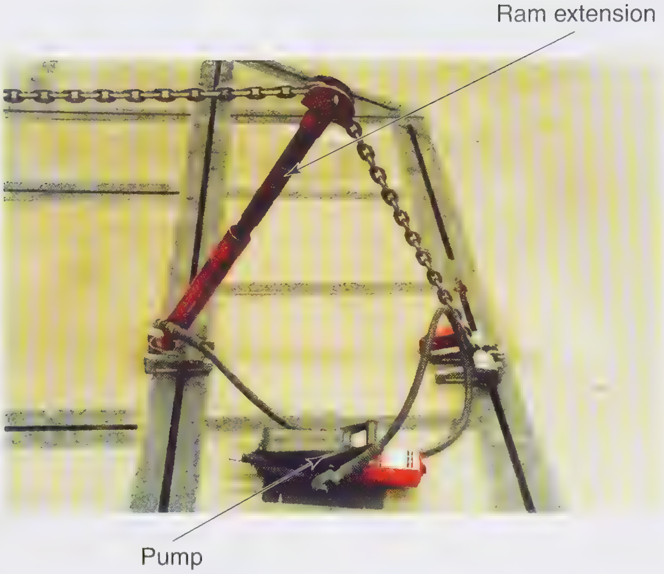


Figure 13-29. *This is a ram setup. An air hose is connected to the pump. The air powers the hydraulic pump, which in turn powers the ram.*

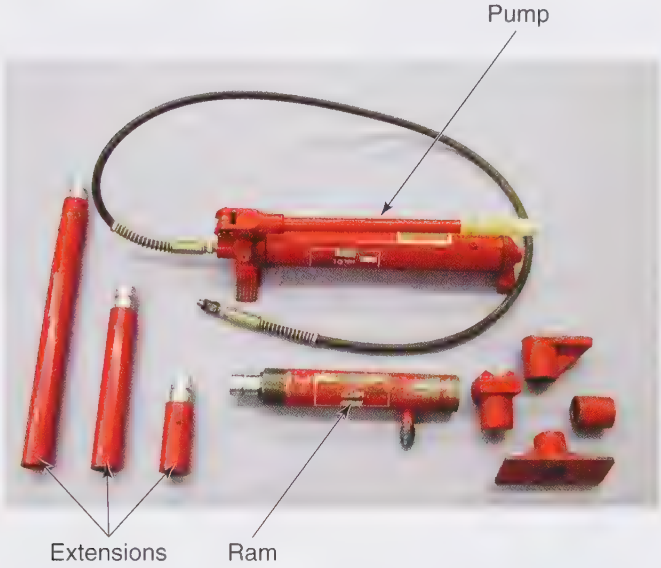


Figure 13-30. *This ten-ton hydraulic power set includes a hand pump, ten-ton ram, extensions, and various attachments for the extensions.*

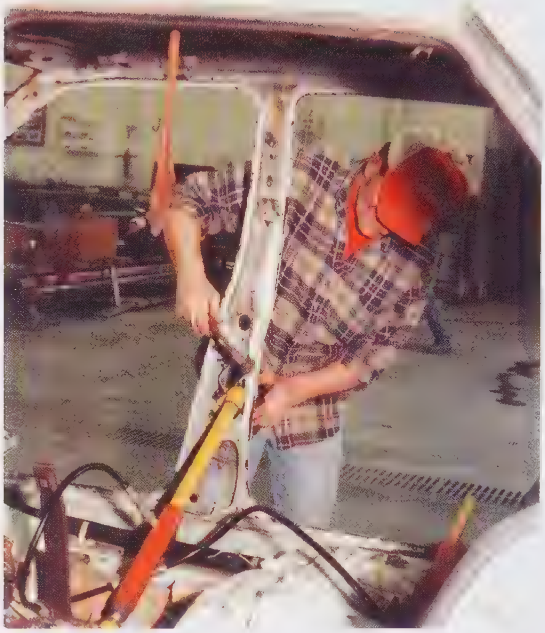


Figure 13-31. *A hydraulic ram, extensions, and an attachment based at the center hump of a vehicle are used to push on a damaged center pillar.*

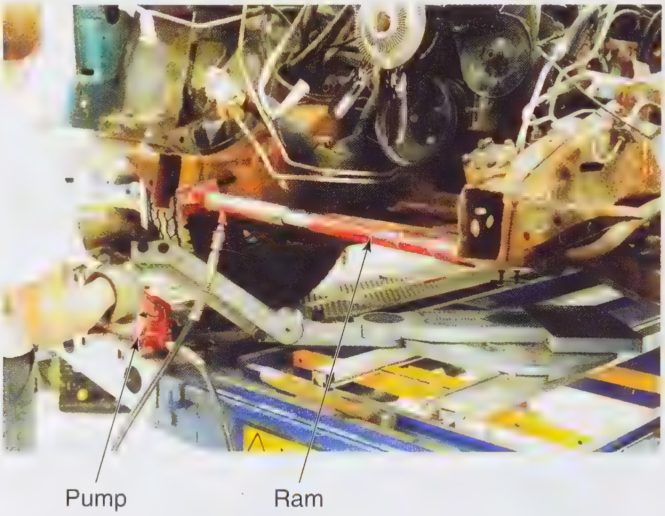


Figure 13-32. *A hydraulic ram, an extension, and an attachment are used to spread the frame rails on a pickup truck.*

of the unibody where the base is placed must be able to resist the pushing force of the ram.

In **Figure 13-31**, a ram is set up to push out a damaged center pillar. Extensions are used to reach the damage. The ram is placed against the hump in the center of the vehicle. When using this setup, make sure the force is spread out enough that the hump and center pillar are not damaged.

A ram used in a full-frame repair is shown in **Figure 13-32**. The ram is set in between the frame rails. The push is made against the damaged rail. As in the unibody example, the ram will push against the base as hard as it pushes against the damage, and the weakest area will move. There are two ways to make sure the damaged area moves instead of the base. One way is to use a tie-down to immobilize the undamaged frame rail for a side push or blocking for an upward push. The other way is to weaken the damaged area by heating. Check the manufacturer's recommendations to see if heating is allowed.

During frame repair, rams and extensions can be positioned to raise portions of the frame or to serve as blocking. The ram is based against the floor or the bed of the frame machine. As the ram extends, the vehicle is raised. With the correct setup, pushing equipment can be used in structural repair. See **Figure 13-33**.

A pull ram is shown in **Figure 13-34**. The action of the pull ram is opposite that of a conventional ram. The pull ram is extended and attached to chains at either end of the ram. The action of the hydraulic pump causes the ram to contract, pulling the chains together. Any type of pull is possible, as long as the pull ram is attached to an unmovable object. For example, a pull ram attached to the floor can make a downward pull on a frame rail that has been pushed up by collision damage.

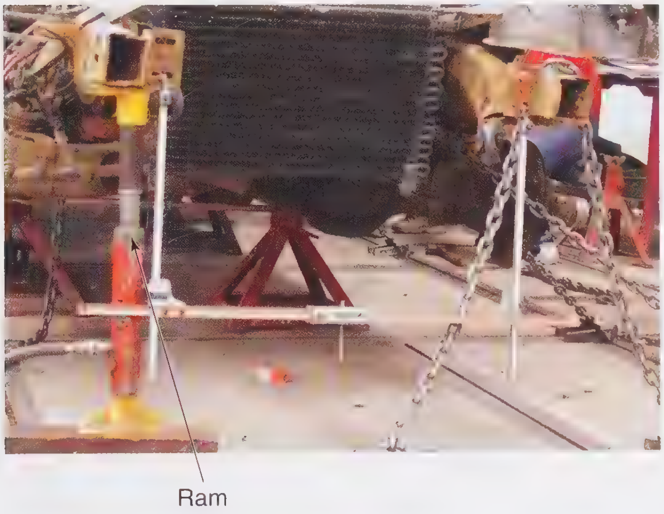


Figure 13-33. *This 10-ton hydraulic ram is used to push up on the right frame rail to straighten the frame damage.*

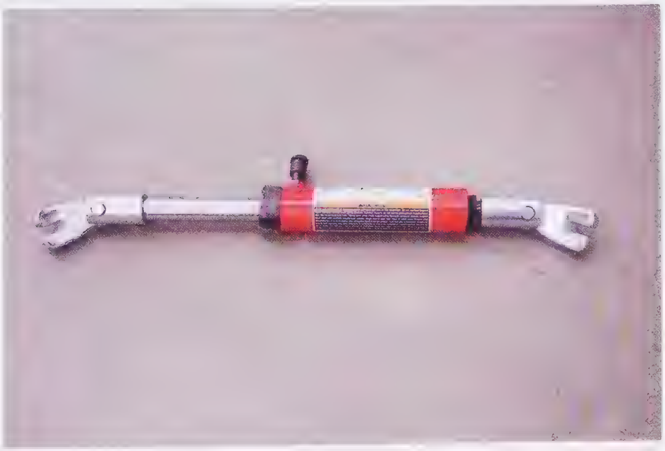


Figure 13-34. *A pull ram is extended and then attached to chains. Cranking the hand pump causes the ram to contract, pulling the chains closer together.*

Pulls

The ***pull*** is the power behind the straightening process. There are three methods of pulling used on frame machines. They all move metal, but each requires slightly different set up techniques. All pulls can "run out of ram." This means that the ram is fully extended before the damage is pulled out. To minimize this problem, remove as much slack in the tie-downs, hookups, and pull chain as possible before pulling. As the pull is made, the tie-downs, hookups and pull chain will tighten. Once these are tight, the damage should start to straighten. If the ram fully extends before all of the damage is pulled out, release the pressure on the ram. The vehicle will settle back once the tension is gone. Take out any slack in the pull chain and begin extending the ram again.

Tower Pull

A ***tower pull*** is shown in **Figure 13-35**. The collar and roller can be moved up and down the tower as necessary. The bottom side of the roller should be positioned at the height of the pull. As the ram either extends or retracts, the chain is pulled around the roller. If the bottom of the roller is positioned level with the damage, a forward pull is made. If the bottom of the roller is positioned below the damage, a combination of forward and downward pulls is made. Positioning the roller above the damage produces a forward and upward combination pull. Tower extensions can be added to allow pulling on roofs of vans and other tall vehicles.

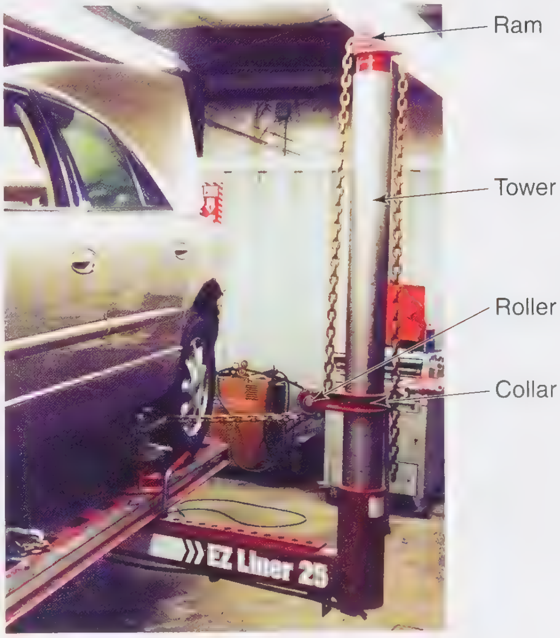


Figure 13-35. *The collar location on the tower pull determines the height of the pull.*

Vector Pull

On a ***vector pull***, the chain is stretched from the hookup to a chain anchor. A ram is positioned in between a foot and the chain, **Figure 13-36**. As the ram is extended, the chain tightens. Further extension of the ram causes the damage to move. The direction of the pull is determined by the ram position on the chain. **Figure 13-37** shows the variety of pull directions possible with vector pulls. Downward pulls should be made with

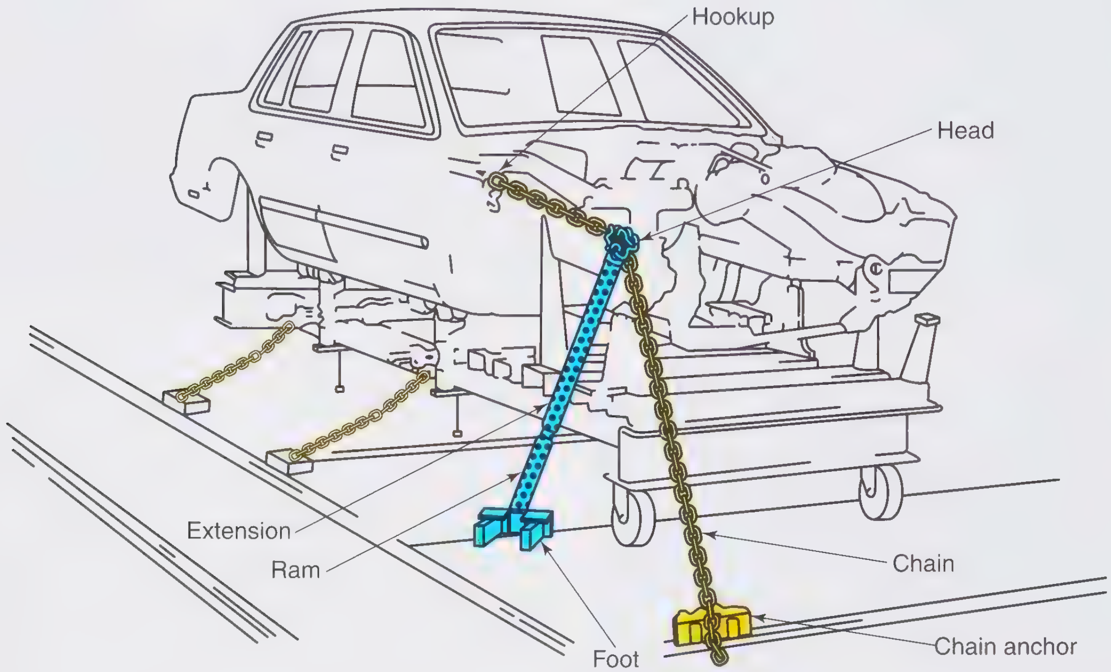
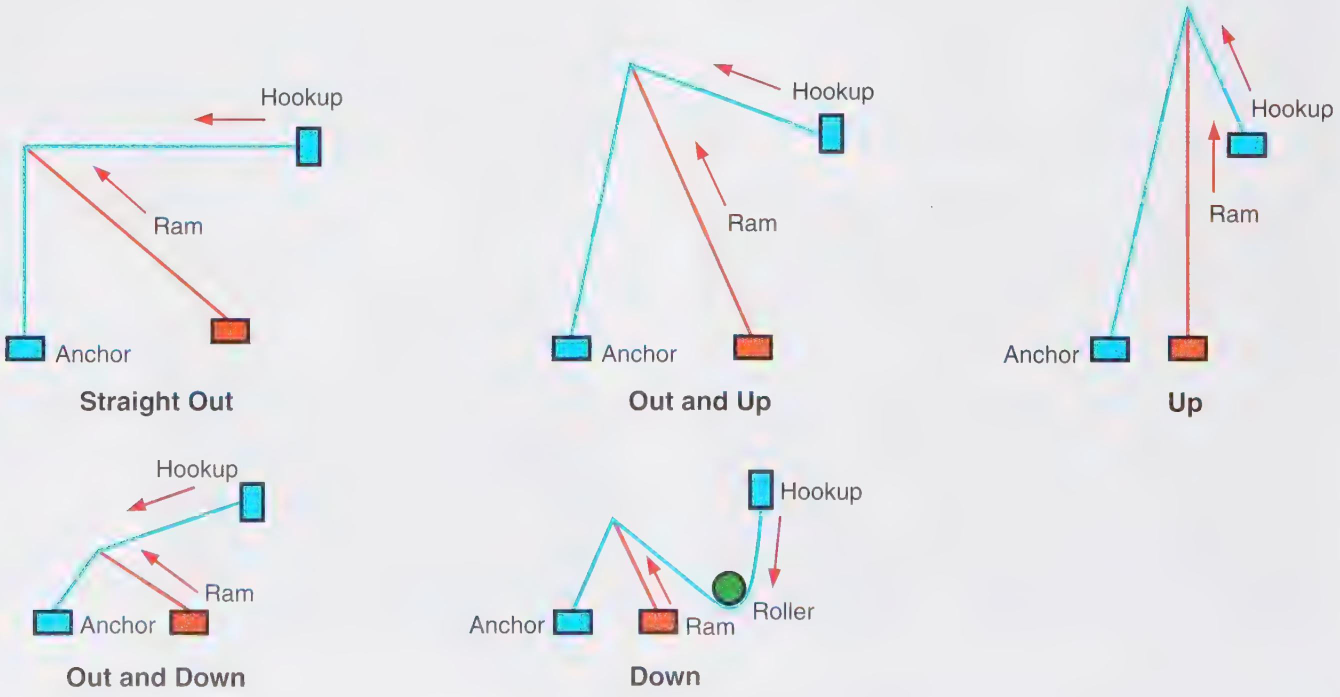

Hookup
Head
Extension
Ram
Chain
Foot
Chain anchor

Figure 13-36. *This is a vector pull. The foot holds the ram, and the head holds the ram to the chain. The anchor immobilizes the chain, and the ram pushes on the chain and the extension. The vehicle cannot move. As the chain is pushed forward by the ram, the damage moves with it.*


Hookup
Ram
Anchor
Hookup
Ram
Anchor
Hookup
Ram
Anchor
Hookup
Ram
Anchor
Hookup
Anchor
Ram
Roller

Straight Out

Out and Up

Up

Out and Down

Down

Figure 13-37. *These are some possible vector pull directions.*

a roller. High pulls can be made by adding extensions to the ram. Pulling power is diminished with a higher pull. Do not position the ram as shown in **Figure 13-38**. This set up may allow the chain to slip out of the anchor under tension. If a forward pull is made on a badly sidewayed rail, as shown in **Figure 13-39**, the foot is placed in line with the correct position of the rail. The chain tie-down is also in line with the correct rail position. When the chain is set up from the chain tie-down to the hookup, the ram will look offset. However, as the ram extends and the rail moves forward and sideways, the ram will be in line with the correct rail position.

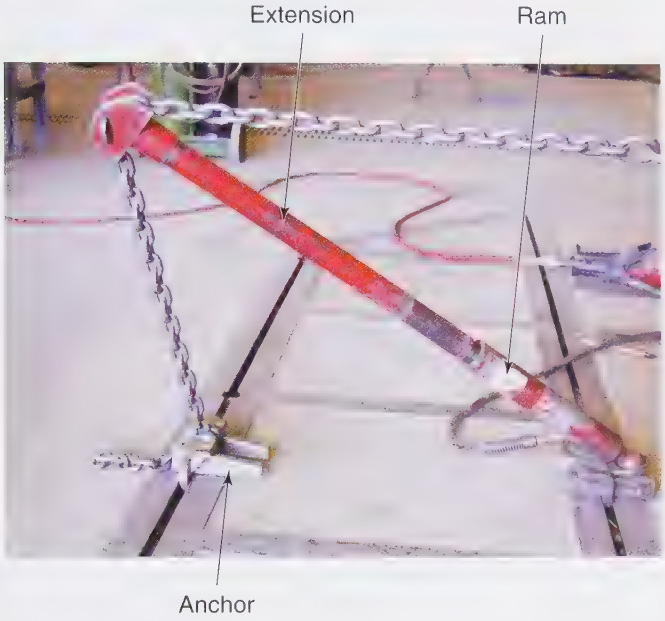


Figure 13-38. *This is a dangerous setup. Notice that the chain looks like it can be pushed out of the anchor.*

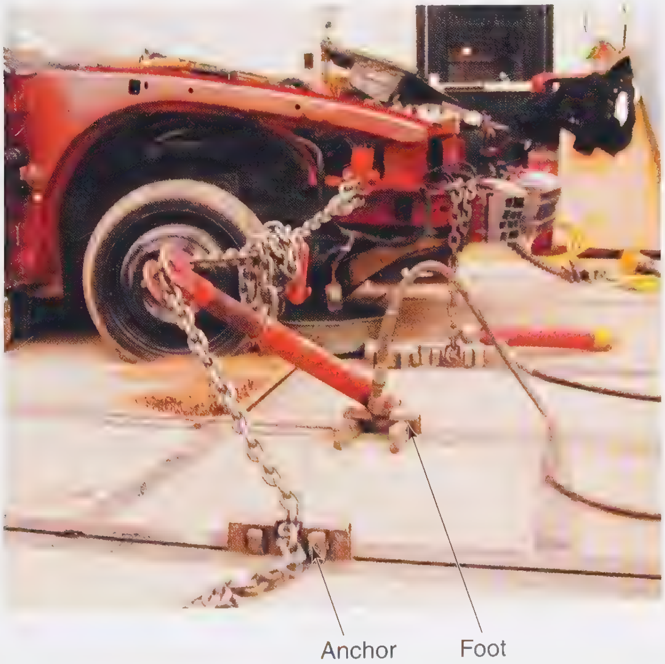


Figure 13-39. *Position the anchor and foot in line with the correct location of the damage. As the vector pull is made, the pull will align the damage.*

Swing Arm Pull

Swing arm pulls are shown in **Figure 13-40**. In this type of pull, the pull chain is attached to the swing arm. A ram extends and pushes the swing arm away from the vehicle. As the swing arm moves, the chain is tightened. The chain can be positioned at any slot along the swing arm. As with a tower pull, if the chain is positioned above the damage, a forward and upward combination pull is made. If the chain is positioned below the damage, a

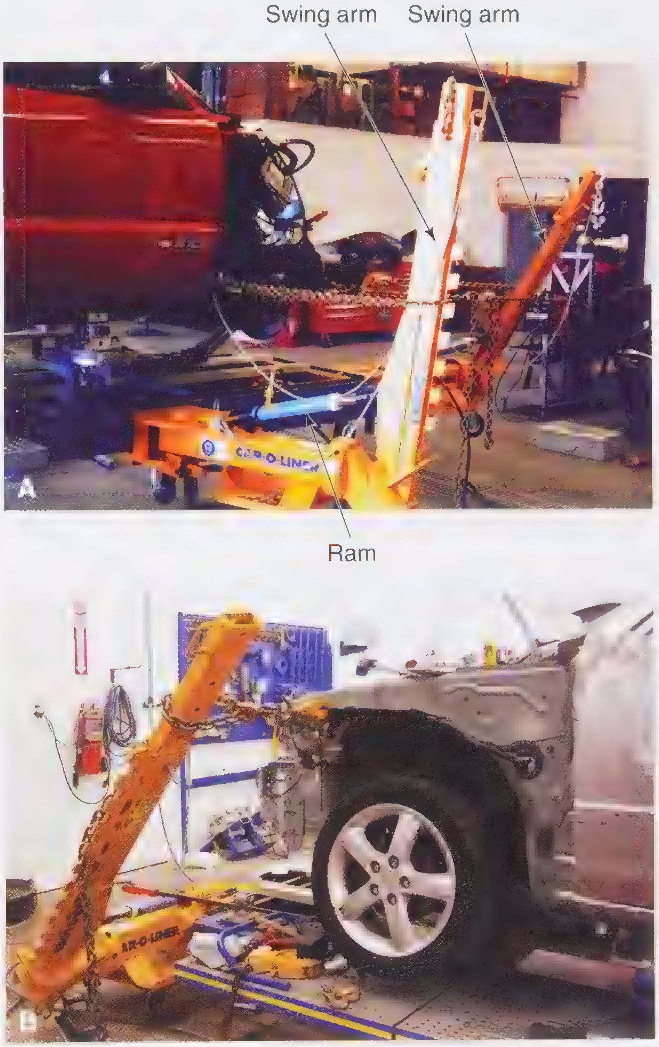


Figure 13-40. *A swing arm pull moves the chain in an arc. A—The swing arm moves the chain down and away from the vehicle. B—The swing arm can tilt to position the pull in the exact location.*

forward and downward combination pull is made. Extensions may be added to the swing arms to reach the roof of tall vehicles. However, as with a vector pull, a higher pull has less power.

Frame Machine Types

There is a wide variation in frame machine design. At the simple end of this spectrum are portable frame machines. These machines consist of simple levers. At the complicated end of the spectrum are drive-on frame machines. These are massive machines, capable of supporting the weight of the vehicle. Regardless of the design and complexity, all frame machines must somehow pull on damaged areas and prevent the vehicle from moving toward the pull. Factors that make one type of frame machine more useful than another include how easy it is to mount the vehicle on the frame machine and how much access is available to the underside of the vehicle once the vehicle is mounted.

Structural damage varies. Portable equipment may be preferred for the repair of slight damage because the portable equipment sets up quickly. Drive-on frame equipment is better suited for the repair of heavy damage because of easier access to the underside of the vehicle. Some shops may have only one type of frame machine.

Portable Systems

A ***portable system*** is a frame machine that can be moved from one stall to another by one person, **Figure 13-41**. This system is based on a reinforced steel rail that serves as a backbone. For full-frame vehicles, the rail is anchored at a cross member or a chain is hooked to the frame and the rail. For unibody repair, rocker flange clamps are bolted to the two corners of the unibody's center section. A bar is slid into the two clamps. The rail is anchored against the bar.

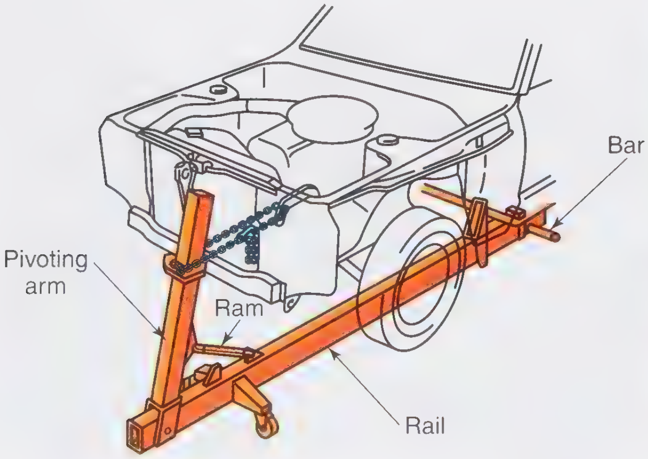


Figure 13-41. *A single-rail portable system. The ram pushes against a stationary mount and the swing arm. As the ram extends, the swing arm pivots, exerting a pulling force on the chain.*

The rail system uses a ten-ton ram to push against a stationary mount and a swing arm. As the ram extends, the swing arm pivots. The pull chains are attached to the swing arm. It is possible to make more than one pull in the same direction using an attachment on the arm.

Another type of machine uses a sliding arm rather than a pivoting arm. A sliding-arm machine is shown in **Figure 13-42**. These types of machines can be used to make a forward pull or even a side pull. However their use is limited; downward pulls are not possible. Rail portable systems are not state-of-the-art, but they can be set up quickly, and if positioned carefully, they can correct simple frame damage.

Floor Pot System

In a ***floor pot system***, **Figure 13-43**, floor pots are used to anchor the vehicle and the towers. Floor pots are cups that hold a length of chain. The floor pots are cemented into the floor. A well-thought-out grid pattern of floor pots allows for maximum versatility. To tie down a full-frame vehicle, the chain wraps are easily hooked to the floor pot chain. For a unibody tie-down, a unirack, shown

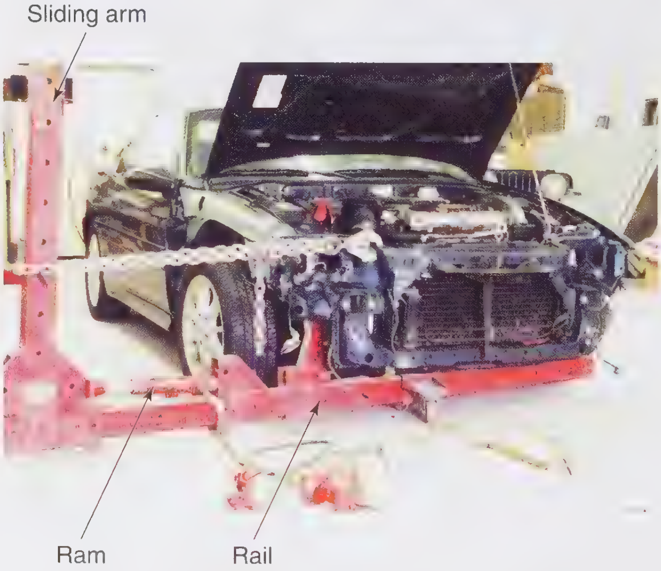


Figure 13-42. *A sliding arm single rail machine is shown pulling the top of a radiator support over.*

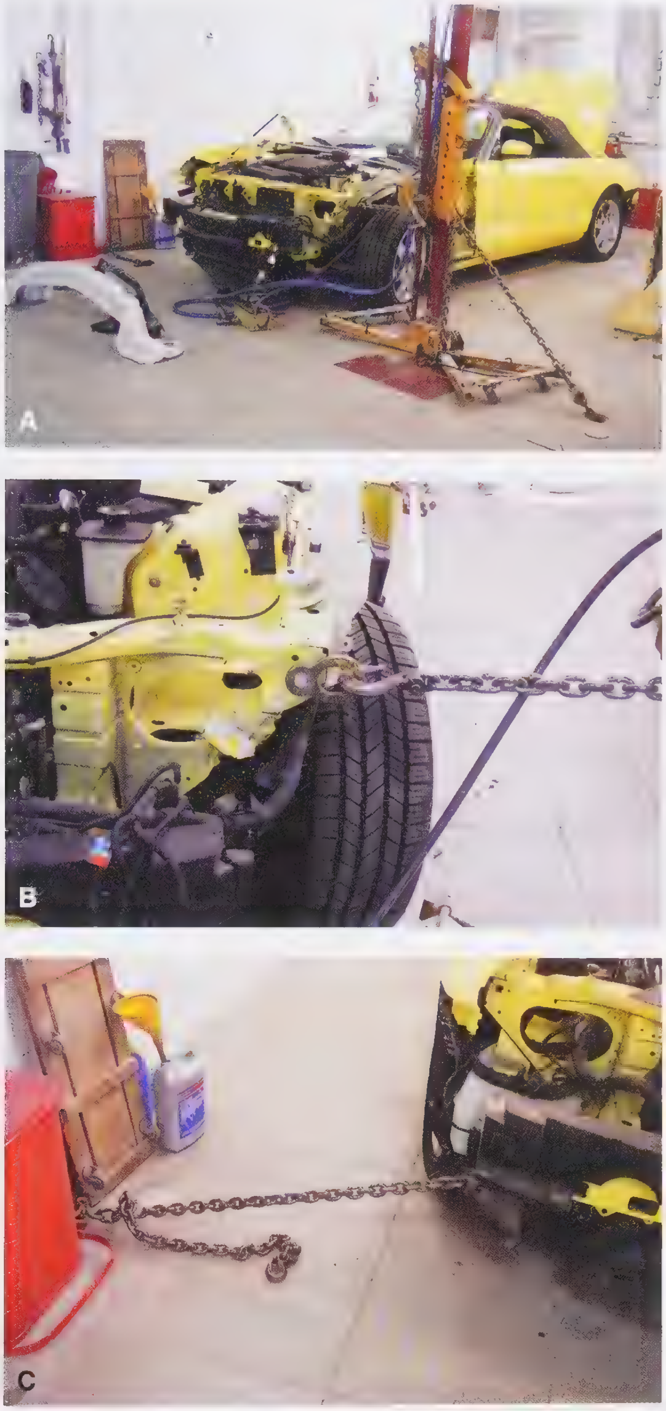


Figure 13-43. *A—This floor pot system is set up to make a quick pull on a radiator support. Notice that the tower is tied to a floor pot. B—The hookup is bolted to a hole in the radiator support. C—The tie-down is attached to the bottom of the radiator support and attached to a floor pot.*

in **Figure 13-44**, is used. The unirack is assembled underneath the vehicle. Pinch weld clamps are bolted to the four corners of the unibody. The bars are slid in and the vehicle is raised on the bars to mount on the stands. The unirack is then tied down to the chains in the floor pots.

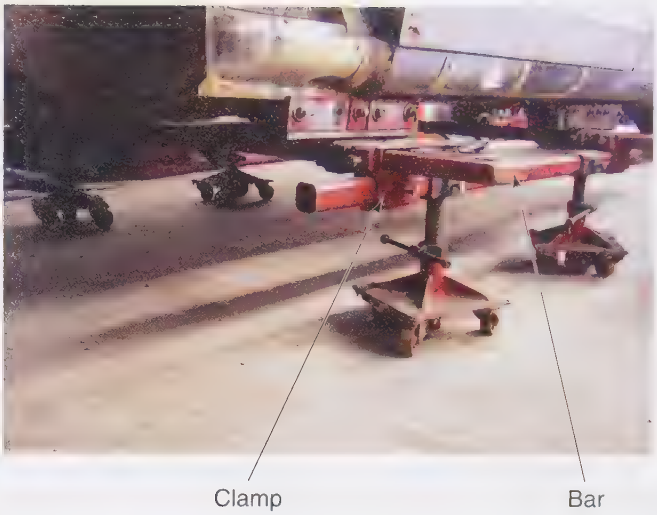


Figure 13-44. *The unirack has clamps that are bolted to the rocker panels and bars that connect the clamps.*

The towers are positioned for pulls and should be tied to two floor pots to prevent excessive pressure on one floor pot. The chain will tighten as force is applied. A 7/16" chain should be used to hold a tower.

For light pulls, such as moving the top of a radiator support, the tie-down chain should extend from the tower to a floor pot in a straight line; for a hard pull, such as pulling two frame rails at one time, the tie-down chain should form a V between two floor pots. The legs of the V should be as close together as possible, **Figure 13-45**. The V shape distributes the force of the pull. Do not attach a chain in between two floor pots, forming a straight line, and then attach the chain tying down the tower to the straight chain. This puts too much stress on the straight chain and the

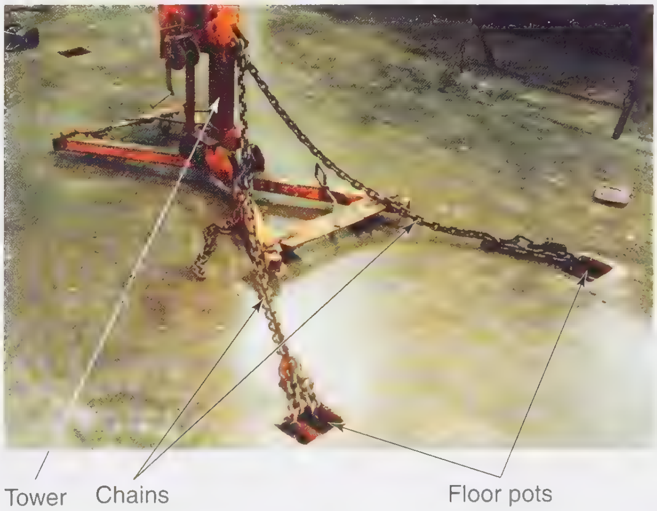


Figure 13-45. *A V-shaped chain set up between floor pots puts less force on the pots than a straight chain between the floor pots.*

floor pots. One of them may break during the pull. When positioning a vehicle in the floor pot grid, consider where the tower will be placed and the pull will be made.

Frame Bench

A ***frame bench*** is a holding and pulling machine onto which the vehicle cannot be driven. The bench is either assembled under the vehicle or the vehicle is raised and the bench is positioned under the vehicle. Then, the vehicle is lowered onto the bench. In addition to holding and pulling the damaged vehicle, a bench can be used to measure.

A dedicated bench, **Figure 13-46**, uses vehicle-specific fixtures to identify damage and position replacement parts. The fixtures are also used to anchor the unibody vehicle to the bench. The term *dedicated* means the fixtures are specific; they only work for one type of vehicle. To measure and anchor a different type of vehicle, the fixtures for that specific vehicle must be obtained and installed on the dedicated bench. **Figure 13-47** shows what fixture misalignment looks like.

A universal bench does not have fixtures. See **Figure 13-48**. This type of bench uses a measuring system of pointers that is set up on the bench to measure each type of unibody vehicle. The pointers are set up according to the instructions provided by the frame machine manufacturer. The position of the pointers identifies misalignment in the unibody. The universal bench can be used to measure and anchor any type of unibody vehicle by setting the measuring system to the specifications for the vehicle being repaired.

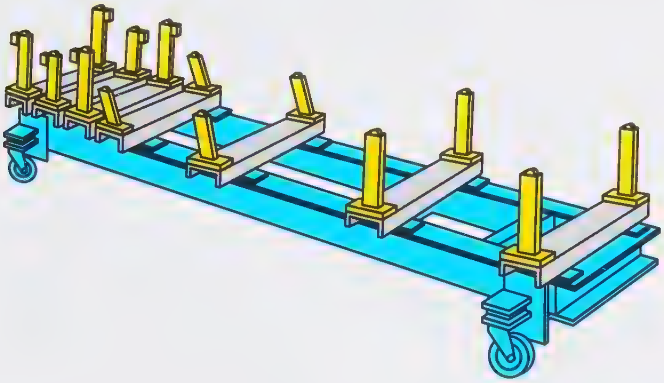


Figure 13-46. *The dedicated bench has specific fixtures.*

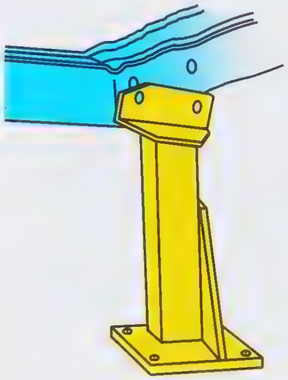


Figure 13-47. *The bolt holes of an undamaged vehicle would line up with the holes of this fixture. The fixture shows that the frame rail needs to move down to align the frame rail bolt holes with the holes in the fixture.*

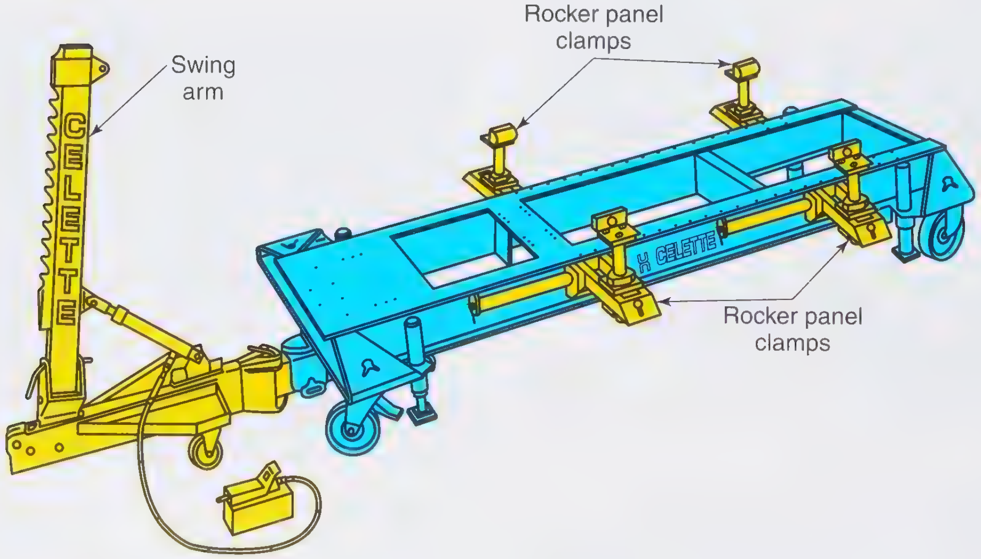


Figure 13-48. *A damaged unibody vehicle would be mounted in the rocker panel clamps on the bench. The swing arm is positioned to pull the damage.*

In most cases, towers can be positioned anywhere around the bench. Down pulls can be made by bolting a down pull wheel onto the bench and pulling from it. Due to the set up time, a bench is best used for medium to heavy structural damage. Light structural damage should be straightened on equipment that is easier to set up.

Frame Rack

A ***frame rack*** is a holding and pulling machine that the vehicle can be driven onto or pulled onto with a winch. Frame racks may tilt to allow easy loading. The number of towers on a frame rack can vary from one to seven. In some designs, the towers roll around the entire machine. See **Figure 13-49**. This allows all the pulling to be done right at the site of damage. This is sometimes called 360° pulling because the entire vehicle is accessible to all the towers. The towers may also tilt to position the pull in just the right spot.

Some frame racks do not have 360° pulling capabilities. The towers on these racks cannot be moved entirely around the vehicle. Instead, the tower or towers are confined to one end of the frame rack. See **Figure 13-50**. If necessary, additional towers can be installed at the opposite end of the rack.

In all frame racks, the vehicle is tied down to the machine and the towers are positioned for pulls. Down pulls can be made by attaching a down pull wheel to the bed of the frame rack or by the method shown in **Figure 13-51**. Any type of measuring system can be used on a frame rack. The vehicle is raised while on the

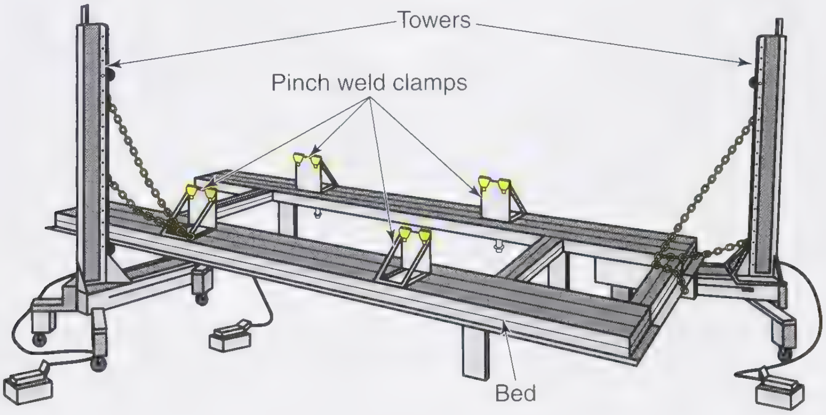


Figure 13-49. *This frame rack can tilt to allow a vehicle to be driven onto the bed.*

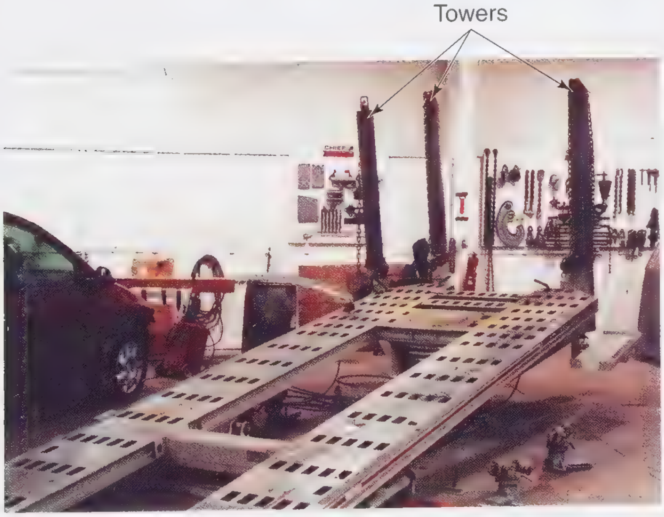


Figure 13-50. *On this type of frame rack, the towers pivot around a central point at one end of the machine. The damaged part of the vehicle must be positioned at the towers. If both ends of the vehicle are damaged, the vehicle must be positioned to repair one end and then repositioned to repair the opposite end.*

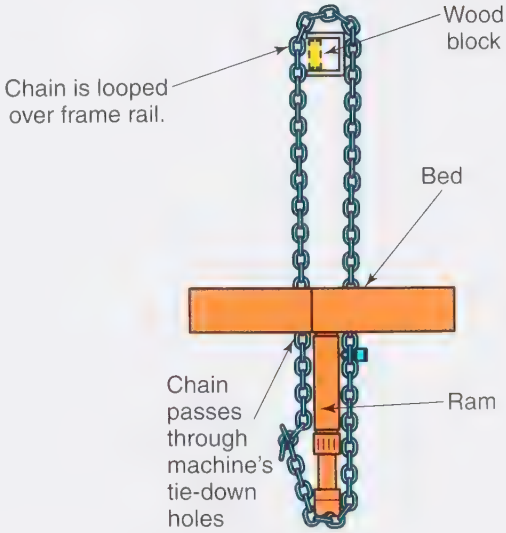

Wood block
Chain is looped over frame rail.
Bed
Chain passes through machine's tie-down holes
Ram

Figure 13-51. *A down pull can be made through holes in the bed of a frame rack with a ram positioned as shown.*

rack so the underside of the vehicle is easily accessible. Any type of frame damage, from light to heavy, can be repaired on a frame rack.

Bench/Rack

A ***bench/rack system*** is a cross between a frame bench and a frame rack, **Figure 13-52**. The vehicle is driven on to the bench/rack. The vehicle is then mounted on the bench. The drive-on ramps are removed, allowing good access to the underside of the vehicle. Towers can be positioned for pulls. Other types of bench/rack systems use rams and chains rather than towers for pulls. This system can be used to repair all types of frame damage.

Floor Rail System

A ***floor rail system*** is shown in **Figure 13-53**. In this system, the vehicle is positioned within the rail grid. A full-frame vehicle can be tied down to the rails with chains. A unibody vehicle can be mounted on a bench or it can be mounted on unibody clamps, cross tubes, and jack stands. The cross tubes or the bench is chained to the rails. A downward pull can be made with a down-pull wheel as shown in **Figure 13-54**. The wheel

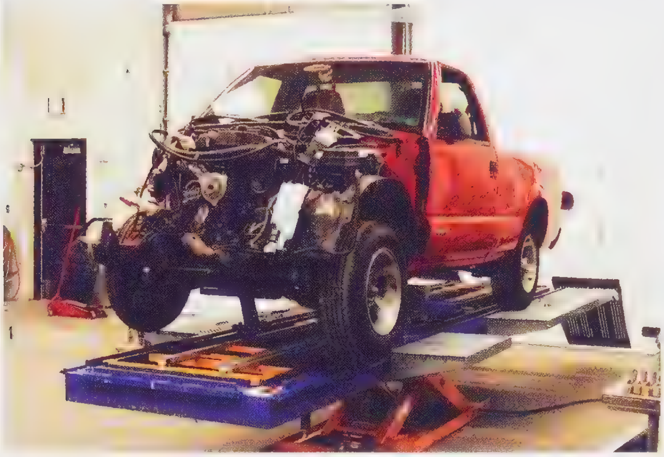


Figure 13-52. *Some of the drive-on ramps remain on this bench /rack. Removal of the ramps allows for better access to the underside of the vehicle.*

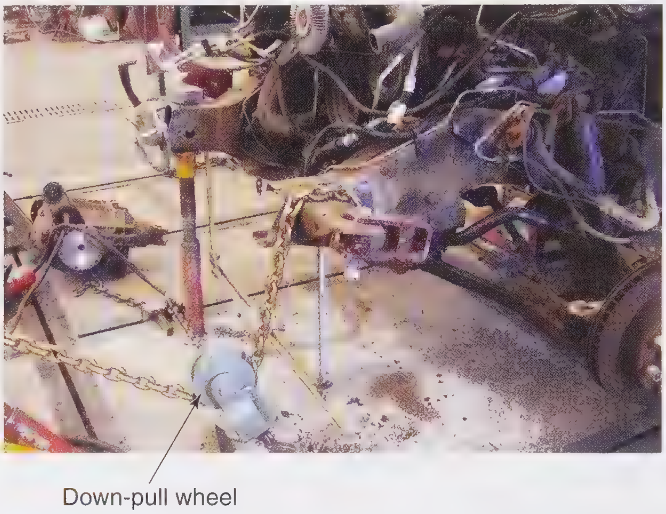


Figure 13-54. *A down-pull wheel is attached to a floor rail. The pull chain is attached to the vehicle and routed through the wheel. The position of the wheel causes the frame to move down when the chain is pulled.*

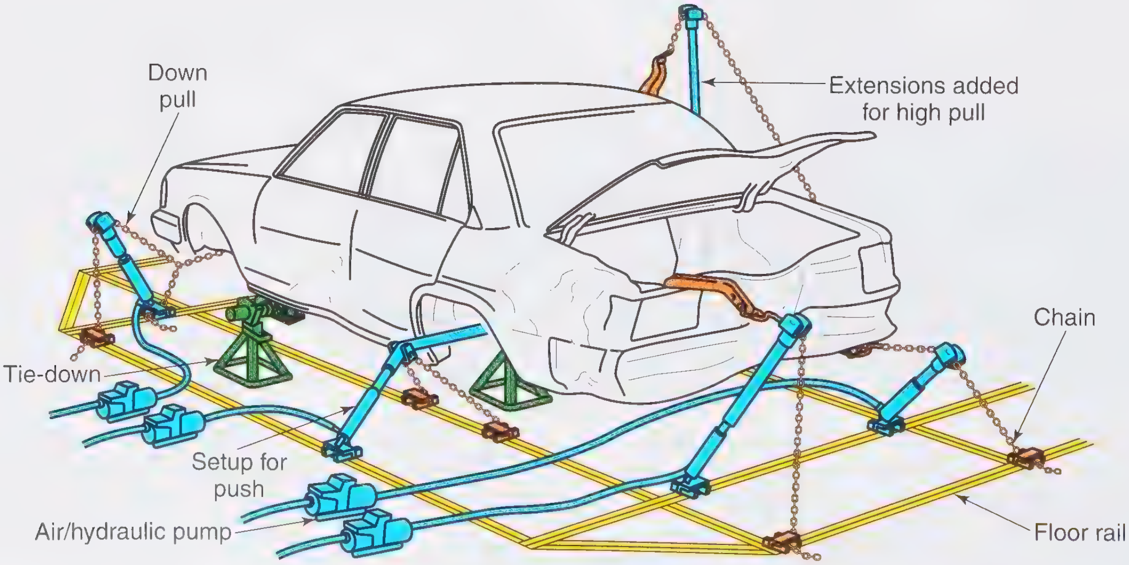


Figure 13-53. *In a floor rail system, the tie-downs, feet, and anchors are held in place by the floor rails.*

is attached to the floor rail so it cannot move up. The chain is set inside the wheel and attached to the vehicle. As the chain is pulled, the wheel turns slightly, allowing the chain to move as the frame is pulled down.

Summary

- A 3/8" chain is used to pull damaged structural components into alignment.
- To prevent flyback, use a safety chain or a chain wrap.
- The three types of chain hooks used in collision repair are the slip hook, the grab hook, and the claw hook.
- Tie-downs are used to hold the damaged vehicle in place so that pulls can be made to align damage.
- Frame wraps can be used to tie down a full-frame vehicle.
- Placing blocking under the frame prevents downward movement of the frame at the location of the blocking.
- Unibody vehicles are tied down with clamps that connect to the pinch weld flanges. The tie-down clamps are placed at the corners of the vehicle's center section
- Hookups are used to attach the pull to the damage.
- After positioning a wedge clamp on the vehicle, tighten the nut so the clamp's teeth bite into the metal. As the clamp is pulled, the wedge forces the clamp tighter.
- A rotating-pull clamp can be used to pull at many different angles.
- A self-tightening clamp is placed inside the open end of a unirail. As the clamp is pulled, it expands and holds onto the unirail.
- Pull plates are designed to be attached to a vehicle with bolts. Use at least two bolts to hold the plate in place.
- Slings are wrapped around damaged rails or pillars. Slings may be made out of steel cable or nylon.
- Frame wraps can be used to hook up to damaged full-frame vehicles and some unibodies.
- The four-ton hydraulic rams used in nonstructural repair are powered by hand-operated hydraulic pumps.
- The ten-ton hydraulic rams used in structural repair may be powered by a hand pump, but they are more commonly powered by an air-powered pump.
- In a tower pull, the bottom side of the roller should be positioned at the height of the pull.
- On a vector pull, the chain is stretched from the hookup to a chain anchor. A ram is positioned in between a foot and the chain. As the ram is extended, the chain tightens.
- In swing arm pulls, the pull chain is attached to the swing arm. A ram extends and pushes the swing arm away from the vehicle.
- Single-rail portable systems are not state-of-the-art, but they can be set up quickly and can correct simple frame damage.
- In a floor pot system, floor pots are used to anchor the vehicle and the towers.
- A frame bench is a holding and pulling machine onto which the vehicle cannot be driven. In addition to holding and pulling the damaged vehicle, a bench can be used to measure.
- A frame rack is a holding and pulling machine that the vehicle can be driven onto or pulled onto with a winch.
- In a floor rail system, the vehicle is positioned within the rail grid.

Review Questions

Please do not write in this textbook. Place your answers on a separate sheet of paper.

1. The minimum tensile strength of pulling chain is ______.
2. Name three types of chain hooks.
3. ______ is used to prevent downward movement of a full-frame vehicle.
4. Explain how frame flanges can be damaged by a tie-down.
5. What size chain is used to make full-frame tie-downs?
6. A tie-down hook prevents movement in all directions. True or False?
7. Most unibody vehicles are tied down by the ______ flanges.
8. How many clamps should be used to tie down a unibody vehicle?
9. If a bolt in a unibody clamp is damaged, it should be replaced with the same size mild steel bolt. True or False?
10. Explain how a self-tightening clamp works.
11. A ______ is used to align a McPherson strut tower.
12. A pull hook that is not properly set up may slip out. True or False?
13. Define a *basket-style pull.*
14. The action of the hydraulic pump causes the pull ram to ______.
15. There should be slack in the tie-down chains before beginning the pull. True or False?
16. On a tower pull, if the bottom of the roller is placed level with the damage, a forward and downward pull will be made. True or False?

17. A high vector pull is stronger than a low vector pull. True or False?
18. On a floor pot system, what size of chain is used to anchor the tower?
19. On what type of frame machine can a vehicle be driven onto the bed?
20. All frame racks have 360° pulling capabilities. True or False?

ASE-Type Questions

1. To prevent chain flyback, Technician A wants to use a chain wrap. Technician B wants to use a safety chain to prevent flyback. Who is right?
   (A) A only.
   (B) B only.
   (C) Both A and B.
   (D) Neither A nor B.
2. Which of the following is caused by overstressing a pulling chain?
   (A) Nicks.
   (B) Gouges.
   (C) Distortion.
   (D) Discoloration.
3. Which of the following is used to prevent downward movement of the frame during pulls?
   (A) Towers.
   (B) Blocking.
   (C) Hookups.
   (D) Swing arms.
4. Technician A says that a large surface is desirable for blocking. Technician B says blocking cannot be used in areas where bolt heads protrude from the bottom of the frame rail. Who is right?
   (A) A only.
   (B) B only.
   (C) Both A and B.
   (D) Neither A nor B.
5. Technician A wants to avoid gas lines when making a frame wrap. Technician B wants to avoid brake lines when making a frame wrap. Who is right?
   (A) A only.
   (B) B only.
   (C) Both A and B.
   (D) Neither A nor B.
6. All of the following can be used to tie a full-frame vehicle down EXCEPT:
   (A) a chain.
   (B) hooks.
   (C) rope.
   (D) clamps.
7. The teeth of a clamp are filled with undercoating. Technician A wants to clean the teeth with a wire brush. Technician B wants to clean the teeth by melting the undercoating with a torch. Who is right?
   (A) A only.
   (B) B only.
   (C) Both A and B.
   (D) Neither A nor B.
8. What grade of bolt is used for replacement in a unibody clamp?
   (A) 2.
   (B) 4.
   (C) 6.
   (D) 8.
9. A unibody pinch weld clamp is not level. Technician A says that this may damage the rocker panel. Technician B says that this will not cause a problem. Who is right?
   (A) A only.
   (B) B only.
   (C) Both A and B.
   (D) Neither A nor B.
10. Technician A says that hookups are used to immobilize the vehicle on the frame machine. Technician B says that tie-downs are used to connect the vehicle and the pull. Who is right?
    (A) A only.
    (B) B only.
    (C) Both A and B.
    (D) Neither A nor B.
11. All of the following are devices used as hookups EXCEPT:
    (A) wedge clamps.
    (B) pull plates.
    (C) towers.
    (D) slings.
12. Technician A says that a pull hook is self-tightening. Technician B says that a wedge clamp tightens as it is pulled. Who is right?
    (A) A only.
    (B) B only.
    (C) Both A and B.
    (D) Neither A nor B.
13. Technician A says that a pull sling may be made out of steel cable. Technician B says that a pull sling may be made out of nylon. Who is right?
    (A) A only.
    (B) B only.
    (C) Both A and B.
    (D) Neither A nor B.

14. A hydraulic power set will be used to move a center pillar on a unibody vehicle. Technician A wants to base the ram on the rocker panel opposite the damage. Technician B wants to use a board to spread the force of the ram. Who is right?
    (A) A only.
    (B) B only.
    (C) Both A and B.
    (D) Neither A nor B.
15. A full-frame vehicle is being tied down before pulling. Technician A wants to leave the tie-down chain loose to allow the vehicle to square itself during the pull. Technician B wants the tie-downs to be tight before the pull. Who is right?
    (A) A only.
    (B) B only.
    (C) Both A and B.
    (D) Neither A nor B.
16. A forward and downward tower pull is needed. Technician A wants to position the roller level with the damage. Technician B wants to position the roller above the damage. Who is right?
    (A) A only.
    (B) B only.
    (C) Both A and B.
    (D) Neither A nor B.
17. A high pull is needed on a vector pull machine. Technician A says that less force is available in a high pull. Technician B says that more force is available in a high pull. Who is right?
    (A) A only.
    (B) B only.
    (C) Both A and B.
    (D) Neither A nor B.
18. All of the following are types of pulls EXCEPT:
    (A) vector.
    (B) swing arm.
    (C) pivot.
    (D) tower.
19. Technician A says that a universal bench is assembled under a damaged vehicle. Technician B says that the damaged vehicle can be driven onto a dedicated bench. Who is right?
    (A) A only.
    (B) B only.
    (C) Both A and B.
    (D) Neither A nor B.
20. A unibody vehicle will be repaired using a floor rail system. Technician A says to mount the unibody vehicle on a bench. Technician B says to tie the unibody vehicle with unibody clamps, cross tubes, and jack stands. Who is right?
    (A) A only.
    (B) B only.
    (C) Both A and B.
    (D) Neither A nor B.

The ability to identify all damage is crucial if repairs are to be done correctly. This bench system checks width, height, and length dimensions on unibody vehicles. (Chief Automotive Systems)

Chapter 14

Measurements

Objectives

After studying this chapter, you will be able to:

- Understand measurements listed in a dimension manual.
- Make linear measurements and compare them to a standard.
- Install and interpret frame gauges.
- Set up and read a mechanical 3-D measuring system.
- Install and use a computer-aided measuring system.
- Draw a damage diagram.

Technical Terms

asymmetrical
base centerline gauges
centerline
centerline gauge
comparative laser
comparison
computer-aided measuring systems
cone
control points
damage diagram
datum
dedicated bench
dimension sheet
dimensions
gauging
height
jigs
laser measuring system
legend
length
measuring arm
measuring bridge
one-dimensional measurements
pendulum effect
set-up sheets
specification
standard
strut tower gauge
symmetrical
target bases
three-dimensional measurements
tolerance
tram
two-dimensional measurements
universal bench
width
x-check

Introduction

While direct damage is easy to identify, indirect damage can be very subtle. Panel gaps and panel alignment will provide clues to the location of indirect damage. However, to identify all damage, the vehicle must be measured. Accurate measurements will reveal all the damage so the vehicle can be repaired to specifications in the minimum amount of time.

If measurements are not taken, indirect damage may be overlooked, causing backtracking when replacement panels do not line up as the vehicle is being repaired. Backtracking is a waste of valuable time and effort. To avoid backtracking, always measure damaged vehicles and locate all indirect damage.

Linear Measurements

Linear measurements are straight-line distances between specified points on a vehicle. There are four types of linear measurements that can be taken on a vehicle.

- Width—***Width*** is the distance from a point to the vehicle's centerline. The ***centerline*** is an imaginary plane that runs down the center of a vehicle, dividing the vehicle into left and right halves. An example of centerline is shown in **Figure 14-1**. The centerline is not stamped or marked on the vehicle; it is simply a reference used in measurement. Width is measured perpendicular to centerline, or to the left or right of centerline.
- Height—***Height*** is the distance of a point above datum. ***Datum*** is an imaginary plane underneath the vehicle. See **Figure 14-2**. All height measurements are referenced to datum. Datum, like centerline, is a reference only. It exists only on paper, not on the vehicle. Height measurements are taken parallel to centerline and perpendicular to datum.
- Length—***Length*** is the distance between two points measured parallel to the centerline. **Figure 14-3** shows an example of length.
- x-check—An ***x-check*** is a pair of linear measurements that cut across one of the planes—centerline or datum—as shown in **Figure 14-4**. The legs of the "x" are compared to each other. The x-check will determine if the measured area is square. If it is square, the legs of the "x" will be equal in length.

To determine if damage or misalignment is present, the linear measurements are compared to a ***standard***. There are two types of standards. The first type of standard, called a ***specification***, is taken from published data shown on a dimension sheet. A ***dimension sheet*** lists several dimensions from an undamaged vehicle. The dimension sheet in **Figure 14-5** is a bottom view showing the vehicle centerline with width measurements. Various locations on the vehicle are identified as measuring points. The ***legend***, located on the right side of the dimension sheet, helps the technician locate the various measuring points on the vehicle. The legend lists the type, shape, and size of various measuring points. For example, the legend may specify the head of a bolt, a cradle mount, and the center of a 9 mm (3/8 inch) hole as measuring points. With this information, the points can be more easily identified on the vehicle.

Symmetrical measuring points are the same distance from the centerline, the same height from datum, and the same distance in length measurement. If any one of the measurements is not the same, the measuring points are ***asymmetrical***. The term *asymmetrical* applies only to specified measuring points, not to the vehicle itself.

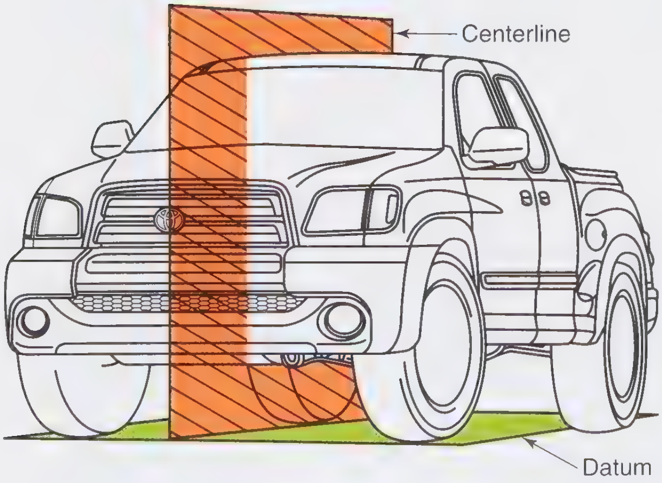


Figure 14-1. *Centerline is an imaginary line down the center of the vehicle. Width measurements are taken from centerline.*

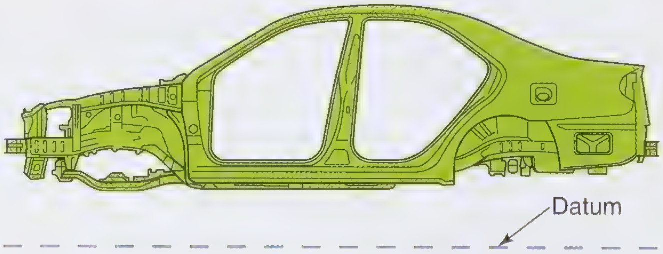


Figure 14-2. *Datum is an imaginary plane under the vehicle. Height measurements are taken from datum.*

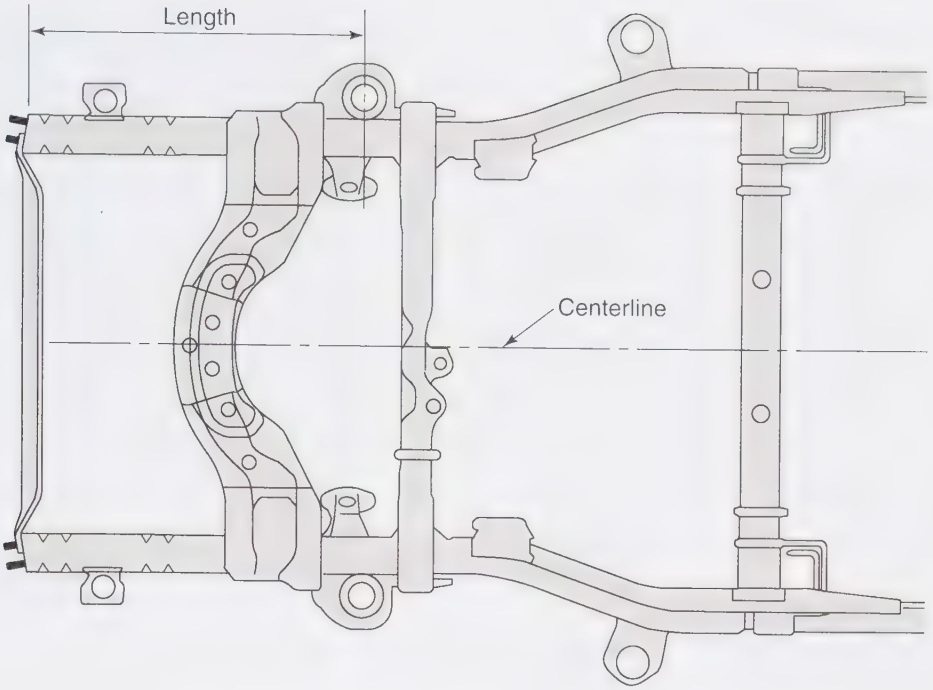


Figure 14-3. *A length measurement is the distance between points parallel to the centerline. (Chief Automotive Systems)*

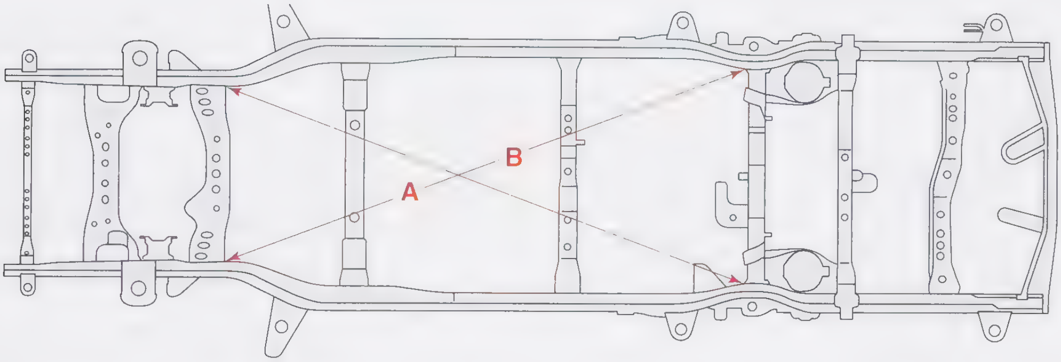


Figure 14-4. *An x-check is used to make a quick check for square by comparing the two legs of the "x." If the legs are not equal, the opening is not square. (Chief Automotive Systems)*

The second type of standard, called a ***comparison***, is a dimension taken from an undamaged vehicle of the same type or an undamaged portion of the vehicle being repaired. For example, if the right front door opening on a vehicle is damaged but the left front door opening is not, measurements can be taken from the undamaged side and compared with those taken from the damaged side. If both front door openings are damaged, a vehicle of the same type can be measured for comparison.

The linear measurements of width, height, and length are also known as ***dimensions***. The location of measuring points on a vehicle can be located by referring to one or more of these dimensions. A one-dimensional measurement is of length, width, or height only. A two-dimensional measurement does not include all dimensions. Instead, it is a measurement of width and height. If misalignment is evident, additional measurements would need to be taken to see if the length is inaccurate. A three-dimensional measurement, or 3-D measurement, is a measurement of length, width, and height. This is the most accurate way to measure a vehicle. An example of a 3-D measuring system is shown in **Figure 14-6**. Notice that the pointer is not touching the center of the measuring point. The pointer indicates where the measuring point should be if there is no misalignment. Because the pointer and the measuring point do not touch, there is some type of misalignment in the vehicle.

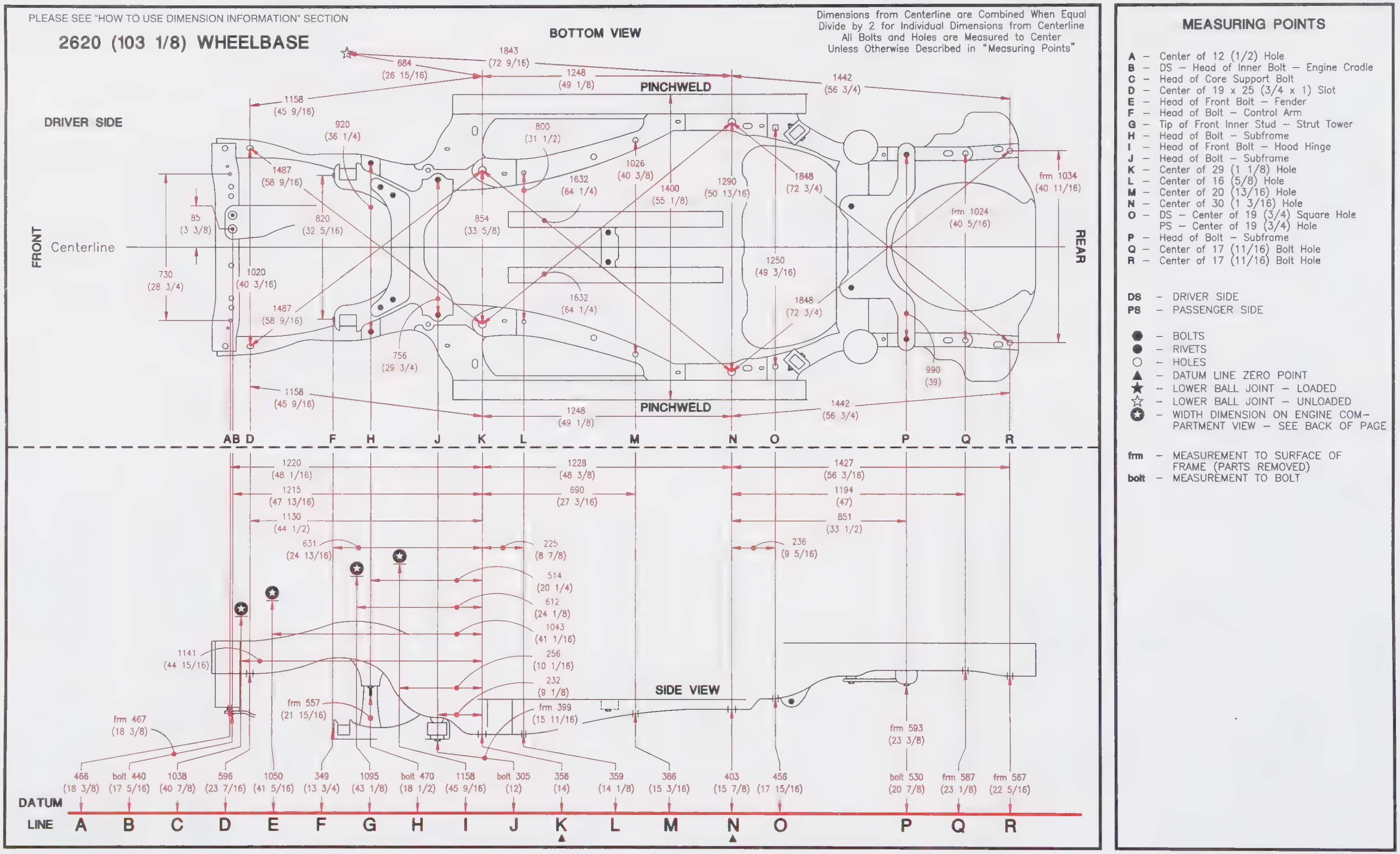

PLEASE SEE "HOW TO USE DIMENSION INFORMATION" SECTION
2620 (103 1/8) WHEELBASE
BOTTOM VIEW
Dimensions from Centerline are Combined When Equal Divide by 2 for Individual Dimensions from Centerline
All Bolts and Holes are Measured to Center Unless Otherwise Described in "Measuring Points"
DRIVER SIDE
FRONT
Centerline
REAR
PINCHWELD
PINCHWELD
1843 (72 9/16)
684 (26 15/16)
1248 (49 1/8)
1442 (56 3/4)
1158 (45 9/16)
920 (36 1/4)
800 (31 1/2)
1487 (58 9/16)
1026 (40 3/8)
1632 (64 1/4)
1290 (50 13/16)
1400 (55 1/8)
1848 (72 3/4)
frm 1034 (40 11/16)
frm 1024 (40 5/16)
85 (3 3/8)
820 (32 5/16)
854 (33 5/8)
730 (28 3/4)
1020 (40 3/16)
1250 (49 3/16)
756 (29 3/4)
990 (39)
AB D F H J K L M N O P Q R
1220 (48 1/16)
1215 (47 13/16)
1130 (44 1/2)
1228 (48 3/8)
690 (27 3/16)
1427 (56 3/16)
1194 (47)
851 (33 1/2)
631 (24 13/16)
225 (8 7/8)
236 (9 5/16)
514 (20 1/4)
612 (24 1/8)
1043 (41 1/16)
256 (10 1/16)
232 (9 1/8)
frm 399 (15 11/16)
1141 (44 15/16)
frm 557 (21 15/16)
frm 467 (18 3/8)
SIDE VIEW
frm 593 (23 3/8)
466 (18 3/8)
bolt 440 (17 5/16)
1038 (40 7/8)
596 (23 7/16)
1050 (41 5/16)
349 (13 3/4)
1095 (43 1/8)
bolt 470 (18 1/2)
1158 (45 9/16)
bolt 305 (12)
356 (14)
359 (14 1/8)
386 (15 3/16)
403 (15 7/8)
456 (17 15/16)
bolt 530 (20 7/8)
frm 587 (23 1/8)
frm 567 (22 5/16)
DATUM LINE
A B C D E F G H I J K L M N O P Q R
MEASURING POINTS
A – Center of 12 (1/2) Hole
B – DS – Head of Inner Bolt – Engine Cradle
C – Head of Core Support Bolt
D – Center of 19 x 25 (3/4 x 1) Slot
E – Head of Front Bolt – Fender
F – Head of Bolt – Control Arm
G – Tip of Front Inner Stud – Strut Tower
H – Head of Bolt – Subframe
I – Head of Front Bolt – Hood Hinge
J – Head of Bolt – Subframe
K – Center of 29 (1 1/8) Hole
L – Center of 16 (5/8) Hole
M – Center of 20 (13/16) Hole
N – Center of 30 (1 3/16) Hole
O – DS – Center of 19 (3/4) Square Hole
PS – Center of 19 (3/4) Hole
P – Head of Bolt – Subframe
Q – Center of 17 (11/16) Bolt Hole
R – Center of 17 (11/16) Bolt Hole
DS – DRIVER SIDE
PS – PASSENGER SIDE
⬢ – BOLTS
● – RIVETS
○ – HOLES
▲ – DATUM LINE ZERO POINT
★ – LOWER BALL JOINT – LOADED
☆ – LOWER BALL JOINT – UNLOADED
✪ – WIDTH DIMENSION ON ENGINE COMPARTMENT VIEW – SEE BACK OF PAGE
frm – MEASUREMENT TO SURFACE OF FRAME (PARTS REMOVED)
bolt – MEASUREMENT TO BOLT

Figure 14-5. *A dimension sheet shows various measuring points on a vehicle. (Mitchell International)*

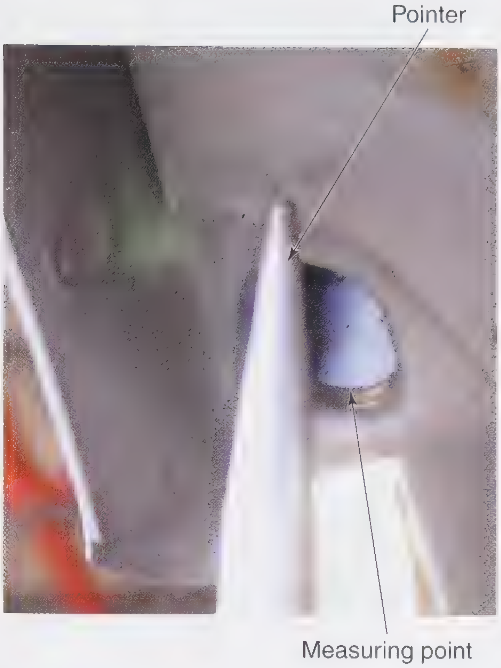


Figure 14-6. *This three-dimensional measuring system pointer does not align properly with the measuring point.*

Dimensions are often grouped into two categories: underbody dimensions and upper body dimensions. Underbody dimensions are taken from holes, slots, or bolt heads on the frame or the underside of a unibody. Upper body dimensions are taken from the engine compartment, door, hood, or deck lid openings. Upper body measuring points can be bolt heads, holes, panel edges, centers of curved openings, or even surfaces.

One-Dimensional Measurements

One-dimensional measurements are measurements taken between two points. When making one-dimensional measurements, the measuring points can be holes, bolts, seams, or rivets. When using a dimension sheet as a specification standard, bolts, holes, and rivets are usually measured from their centers. When measuring between holes of the same size, measuring from the far edge of one to the near edge of the other is the same as measuring from center to center. See **Figure 14-7**.

A ***cone*** is a measuring tool used to find the center of a round hole. See **Figure 14-8**. Mount the cone on a pointer and insert the cone into a round hole until the cone is uniformly touching the edge of the hole. For bolts or rivets, hold the edge of the tape or tram pointer at the center of the fastener.

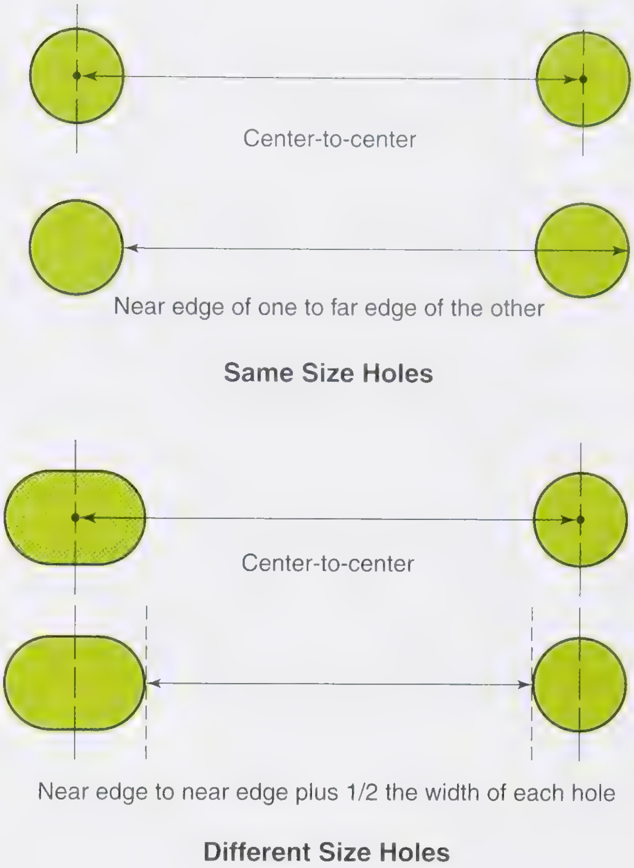

Center-to-center
Near edge of one to far edge of the other
Same Size Holes
Center-to-center
Near edge to near edge plus 1/2 the width of each hole
Different Size Holes

Figure 14-7. *Measuring points, such as holes or bolt heads, are measured from center to center. If the holes are the same size, take measurements from the near edge of one hole to the far edge of the other. If the holes are not the same size, measure from the nearest edge of one hole to the nearest edge of the other hole; then add one-half the width of each hole to calculate the center-to-center distance.*

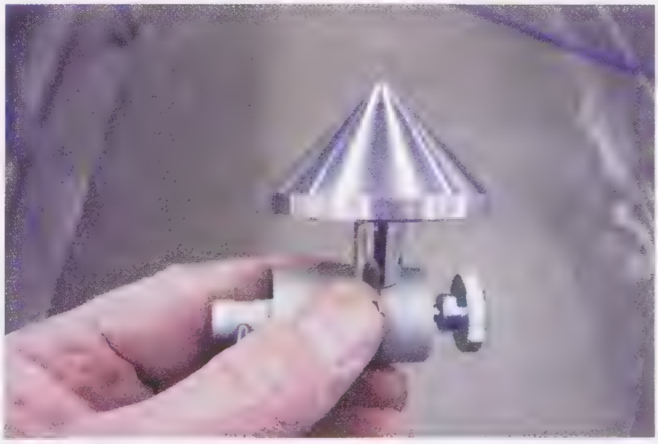


Figure 14-8. *When this tapered cone is inserted into a round hole that is smaller in diameter than the cone, the cone will be centered.*

Measuring center-to-center on odd-shaped holes is difficult. Measure from the nearest edge of one hole to the nearest edge of the second hole. Add to this number half of the width of each hole. This will give you the center-to-center measurement.

WORKING SMART

When using another vehicle as a comparison standard, be sure to use consistent measuring points. For example, hook the tape to the bolt head and measure the distance to another bolt. Repeat the same measurement on the damaged vehicle.

One-dimensional measurements must be within tolerance. ***Tolerance*** is the maximum allowable deviation from the standard. On a full-frame vehicle, the tolerance is 1/4" (6 mm). On unibody vehicles, the tolerance is 1/8" (3 mm). For example, if the standard measurement is 100 mm and the actual measurement is 98 mm, the vehicle is within the 3 mm of standard. In fact, any measurement from 97 mm–103 mm would be within the tolerance.

An x-check of an engine compartment is shown in **Figure 14-9**. This is a quick way to check for damage. Be sure to record the x-check measurements to use as a reference when pulling. If the measuring points are symmetrical, the legs of the "x" should be equal. A measurement that is out of tolerance indicates damage. The tolerance for an x-check is double that for a linear measurement. For a unibody vehicle, the x-check tolerance is 1/4" (6 mm). For a full-frame vehicle, the tolerance is 1/2" (12 mm). A tape measure can be used to make an x-check as long as it can be kept straight and does not have to bend around obstructions. If there are obstructions in the way, use a tram with equal-length pointers.

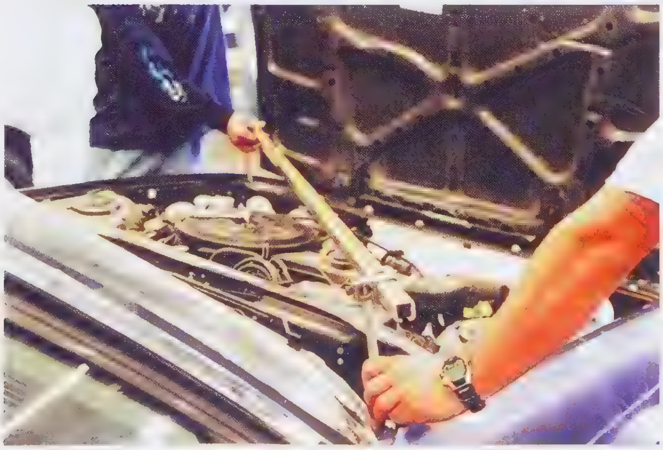


Figure 14-9. *A quick x-check is made of an engine compartment while fitting a replacement hood.*

A door-opening measurement is shown in **Figure 14-10**. A dimension sheet for a door opening is shown in **Figure 14-11**. There are several types of misalignment that can occur in a door opening. A side impact can drive an A pillar or a center pillar inward, a front impact can drive an A pillar or a center pillar rearward, and a rear impact can drive a C pillar or a center pillar forward. A rollover can drive a center pillar or A pillar down and, possibly, outward. Movement of the pillars would cause the door opening measurements to be inaccurate when compared to the standard. Door opening measurements are taken from seams, bolt holes, and the striker. One way to mark a measuring point for accurate repeat measurements is shown in **Figure 14-12**. The measuring point in the upper rear corner of the door opening is marked on masking tape. Consistent measurements can be made to this mark. After the vehicle is repaired, the tape should be removed.

To identify damage inside the passenger's compartment, x-checks can be made as shown in **Figure 14-13**. To isolate the damage, the center section should be divided into upper and lower halves and each half measured separately. This measurement will indicate misalignment of the roof, pillars, and lower body.

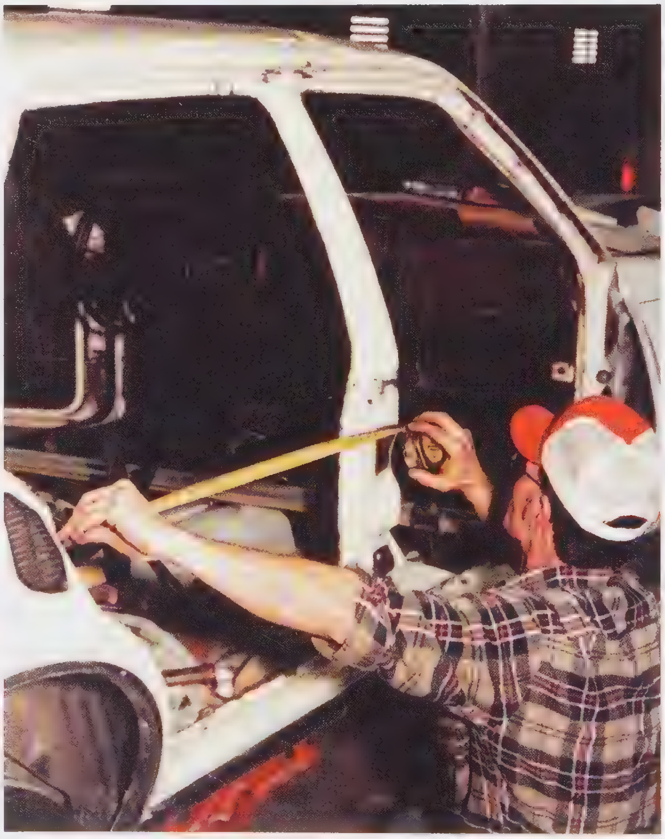


Figure 14-10. *A door measurement is made from the rear door striker to the rear door upper hinge bolt hole. This measurement is used to check center pillar location.*

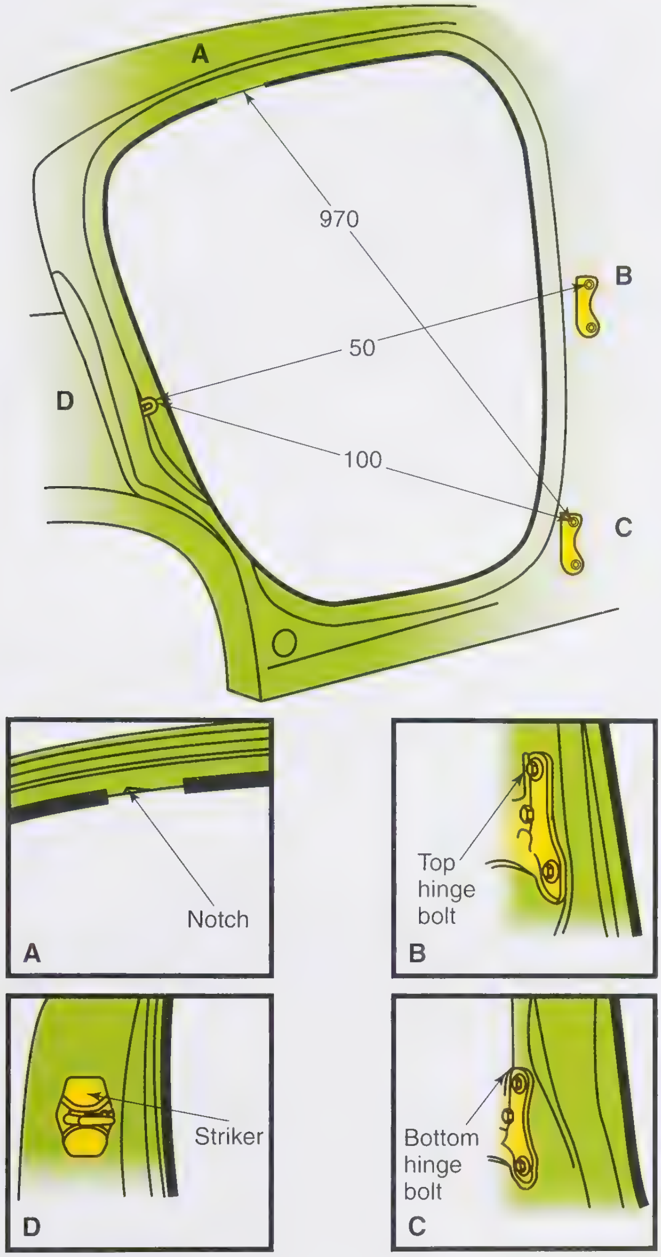

A
970
B
50
D
100
C
Notch
A
Top hinge bolt
B
Striker
D
Bottom hinge bolt
C

Figure 14-11. *The rear door dimension sheet lists linear measurements.*

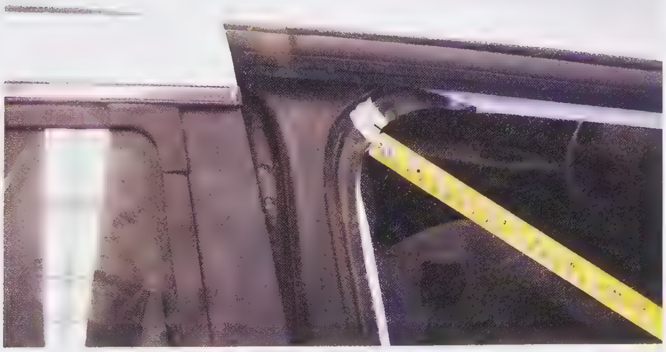


Figure 14-12. *A measuring point is marked on masking tape to allow for consistent measuring during repair.*

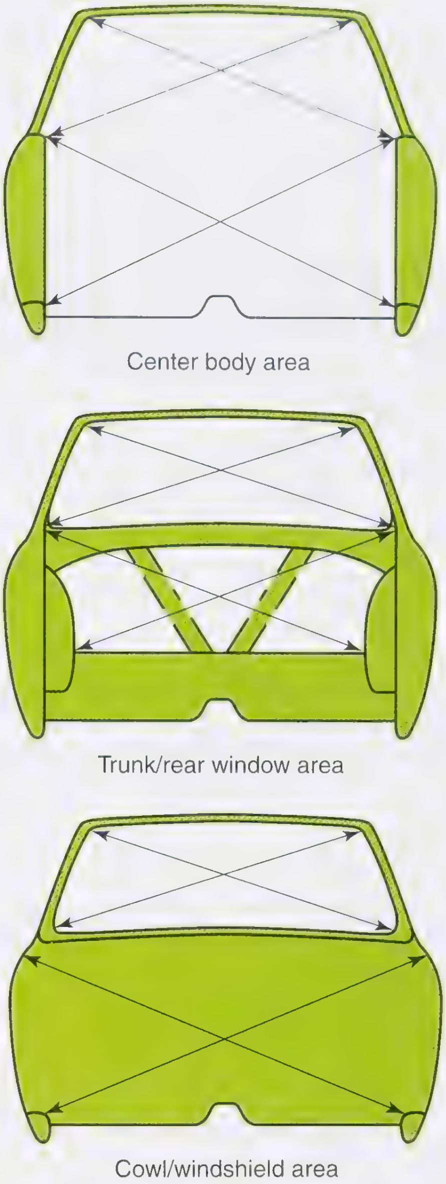

Center body area
Trunk/rear window area
Cowl/windshield area

Figure 14-13. *X-checks can be used to identify damage in the center section of a vehicle.*

One challenge to using a data sheet is that point-to-point distance isn't always given and the distance between points must be calculated using the known values. For example, to convert the datum distance shown in **Figure 14-14** to point-to-point measurement, you must be able to calculate for the unknown side of a right triangle. A calculator with a square root key can be used for this purpose. The distances A, D, and E are given. Distance B can be calculated by subtracting E from D.

B = D – E
B = 100mm – 75mm
B = 25 mm

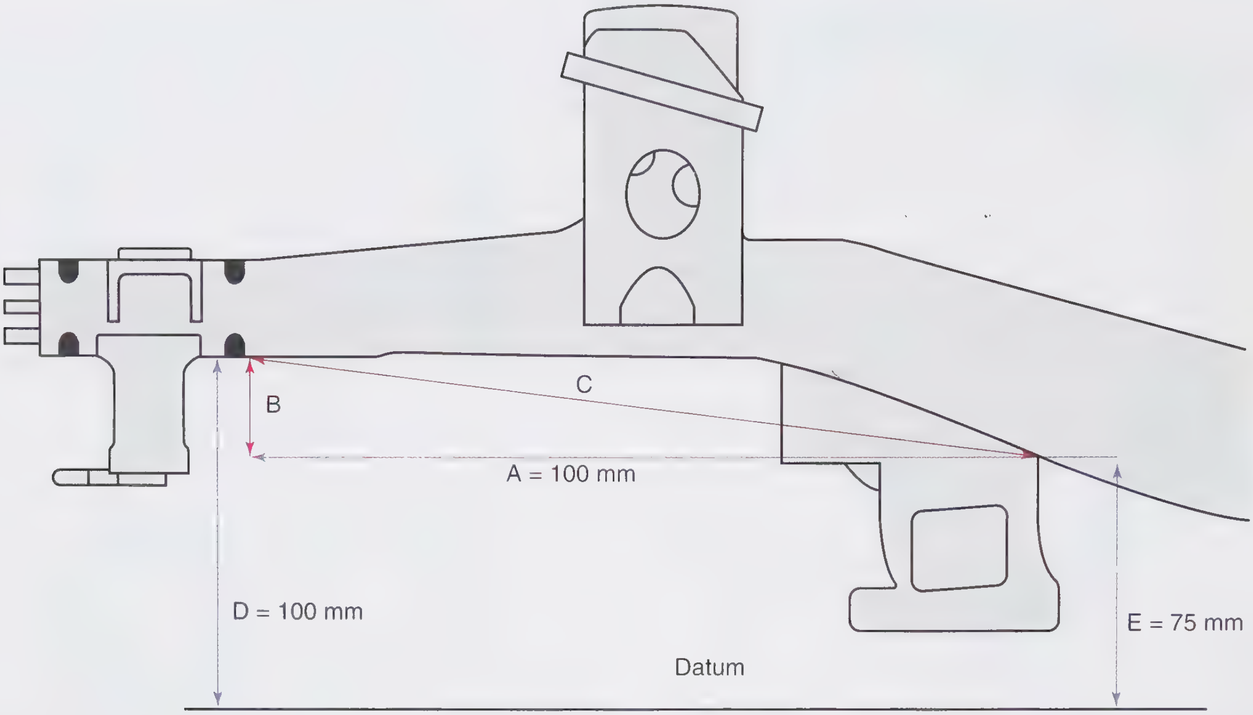


Figure 14-14. *The datum distance between different height measuring points can be converted to a point-to-point distance.*

The measurements A, B, and C form a right triangle. To calculate the length of C, you can use the Pythagorean theorem. The equation for the Pythagorean theorem is:

$A^2 + B^2 = C^2$

To solve for C

$C^2 = A^2 + B^2$

$C^2 = 100^2\text{mm} + 25^2\text{mm}$

$C^2 = 10{,}000\text{ mm} + 625\text{ mm}$

$C^2 = 10{,}625\text{ mm}$

$C = 103\text{ mm}$

A windshield opening can be difficult to measure because windshield corners are round rather than square. If they were square, the technician could start measuring from the right angle of the right corner. **Figure 14-15** shows how to make a measuring point in a round corner. Draw a straight line from the lip of the roof or cowl and from the lip of the A pillar. The measuring point is where the two lines intersect. Make these points on the two upper corners of the windshield opening. From there, a tram gauge can be used to x-check the opening using these points and measuring points on the cowl.

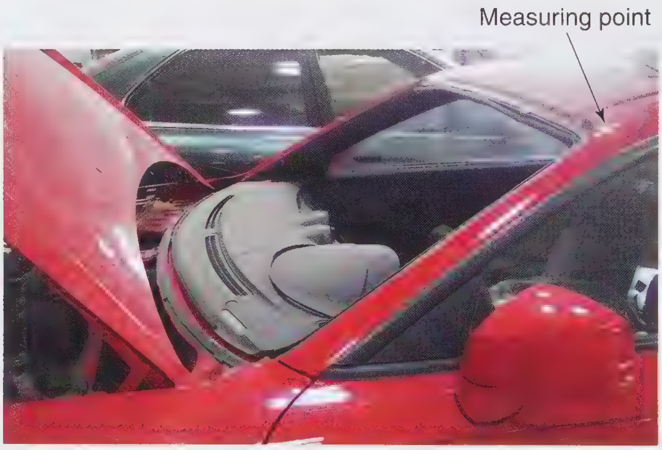


Figure 14-15. *When measuring window openings with rounded corners, draw straight lines from the lip of the roof and from the lip of the A pillar. The spot where the lines intersect is the measuring point.*

Measuring Tools for One-Dimensional Measurements

Tape measures and trams are used to make one-dimensional measurements. The tape measure, **Figure 14-16**, provides a quick way to check linear point-to-point measurements. The tape measure should be marked in both inches and millimeters. The tape should be stretched tight and straight when measuring. Keep the tape clean and rust-free by wiping it with an oiled rag.

A tram is shown in **Figure 14-17**. The ***tram*** is a straight bar with a fixed pointer and a sliding pointer.

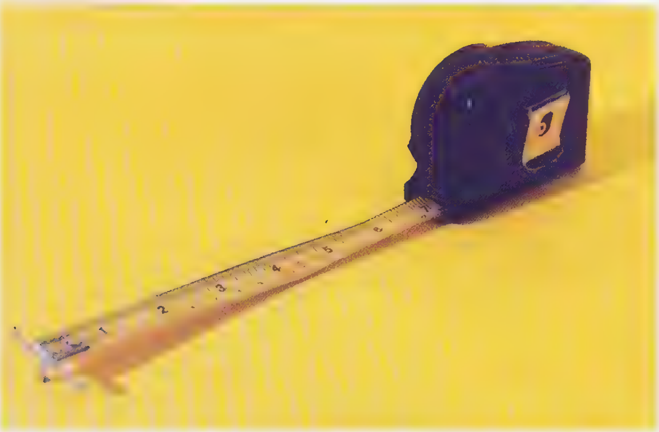


Figure 14-16. *This tape measure has an end that can easily hook into a hole.*

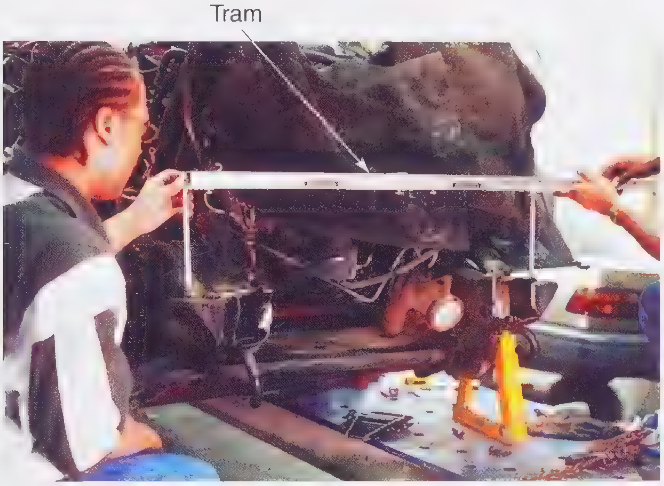


Figure 14-17. *A tram has pointers that slide along the bar. The height of the pointers can be adjusted.*

Pointers of different lengths can be used to reach around obstructions. The tram can be read by adding the numbers in the windows or by measuring the distance between the pointers.

A tram can be used to take two types of measurements, point-to-point measurements and datum measurements. Point-to-point measurements are the same as the measurements taken with a steel tape. The distance between the points need not be parallel to datum or centerline.

A datum measurement, however, is parallel to datum. If the measuring points are at equal heights, the point-to-point measurements will be equal to the datum measurements. If the measuring points are not the same distance above datum, the datum and point-to-point measurements will be different. See **Figure 14-18**.

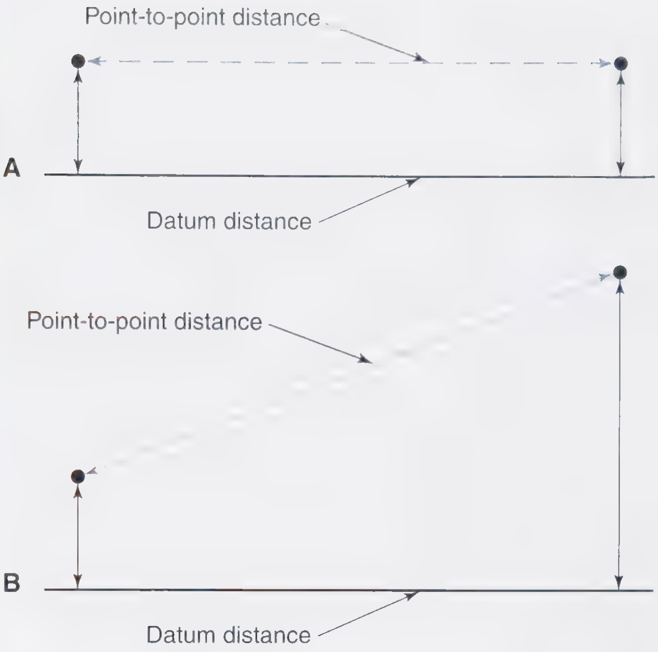


Figure 14-18. *The datum distance is the same in A and B. In A, the measuring points are the same height. In B, the measuring points are different heights. The point-to-point distance is different in A and B.*

To measure datum distance, set the tram pointers to the height indicated on a dimension sheet. This will make the tram bar level with datum. The datum distance can be read off the tram point windows or the distance between the bottom of the pointers can be measured.

A digital tram is shown in **Figure 14-19**. A digital tram has a digital readout to indicate the distance between the two pointers. The tram will measure in inches or millimeters. Simply pull the telescoping measuring arm

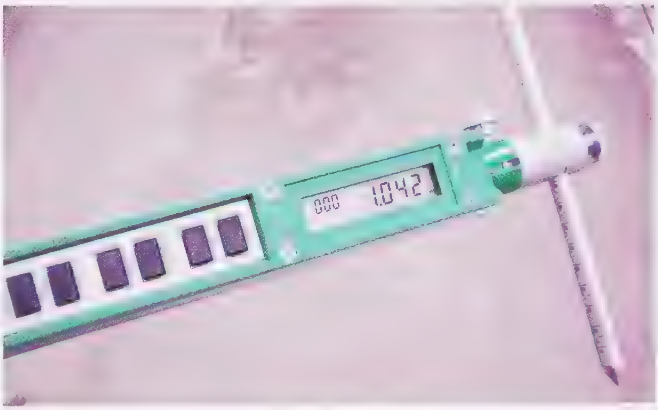


Figure 14-19. *As the tram is extended, the digital readout indicates the distance between the measuring points.*

out of the tram to measure the distance between two points. The minimum distance this tram can measure is 41" (1042 mm).

Two-Dimensional Measurements

Two-dimensional measurements use height and width dimensions to locate a measuring point. Making two-dimensional measurements of a vehicle is referred to as ***gauging***. Gauging measures width related to the vehicle's centerline and height related to its datum. Length measurements must be made separately. Four gauges are mounted to specified measuring points on the vehicle. The gauges hang under the vehicle. If a measuring point is misaligned, the position of the gauge relative to the other gauges will indicate the misalignment.

Measuring Tools for Two-Dimensional Measurements

There are two common measuring tools used to check two-dimensional measurements. A ***centerline gauge*** consists of two horizontal bars, a centerline pin, two rods and two rod attachments. See **Figure 14-20**. Rods of various lengths are attached to the centerline gauge with clamps, allowing the centerline gauges to hang at different heights. Rod attachments allow the rods to be mounted to various types of measuring points. A set of centerline gauges is shown in **Figure 14-21**.

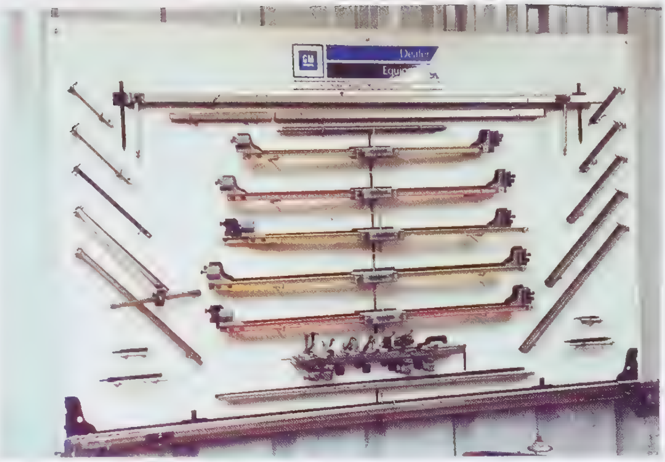


Figure 14-21. *A centerline gauge set includes centerline gauges, various rods, and a tram gauge.*

A ***strut tower gauge***, **Figure 14-22**, is used with centerline gauges on unibody vehicles. The strut tower gauge projects the alignment of the strut towers to the underside of the vehicle, so it can be compared with the centerline gauges. Be careful when handling and storing the gauges. They can be bent if dropped.

Centerline Gauge

When using centerline gauges to check for damage, the checks should be performed in a specific order. If the vehicle is raised so the weight is off the suspension, the front or rear sections may droop. To determine if a vehicle has droop, inspect the door-to-fender gap on both sides of the vehicle with the weight on the suspension. Note whether the gap is even, wide at the top and narrow at the bottom, or narrow at the top and wide at

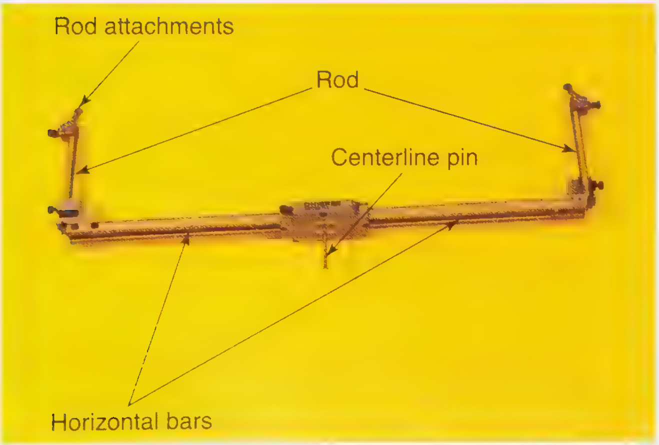


Figure 14-20. *A centerline gauge consists of two horizontal bars, a centerline pin, two rods, and two rod attachments.*

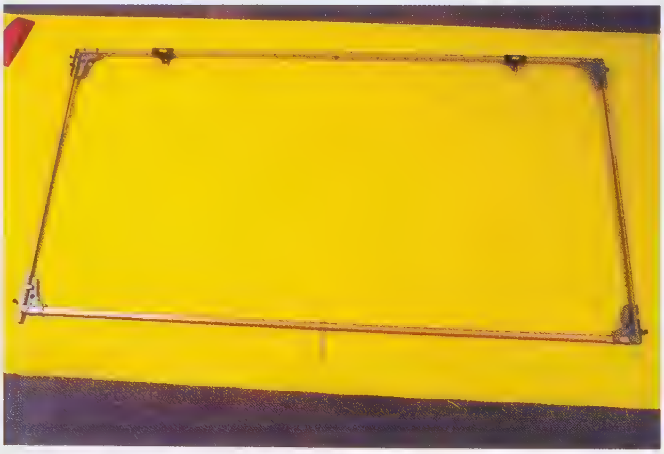


Figure 14-22. *The strut tower gauge is designed to project the centerline of the strut towers under the vehicle.*

the bottom. Next, raise the vehicle by the center section. If the door-to-fender gap does not change on either side, there is no droop. If the gap changes so that it is wider at the top with the weight off the suspension, the front end has droop. If the front end has droop, the centerline gauges can be set to compensate for the slight difference in datum height.

One measuring system manufacturer recommends mounting the gauges on a full-frame vehicle with the suspension loaded (weight on the suspension). However, if droop is not present, a full-frame vehicle can be raised by the center section to install the gauges. Gauges should be mounted on unibody vehicles with the vehicle unloaded.

If the measuring points are the same distance from centerline, each centerline gauge must be centered before it is placed on the vehicle. To center the centerline gauge, pull the bars of the gauge away from each other to the limit.

Do not assume that a gauge is centered before it is placed. Always check centering. Centerline gauges can be set for measuring points that are asymmetrical from centerline. To set a gauge for unequal length horizontal bars, pull each bar to the limit then push one bar in to the required width. Hold that bar in place so it cannot move in while the other bar is set to the proper width. The gauge is ready to place on the vehicle. The following is the sequence to follow when using gauges to check for damage.

Begin by performing an x-check under the center section of the vehicle to locate diamond damage. Diamond damage, **Figure 14-23**, is present when the center section of the vehicle is not square and the end sections may have rotated. If the center section is not square, the front and rear sections will be misaligned also. Diamond damage is much more common in full-frame vehicles than in unibody vehicles. On a pickup truck, x-check the area under the cab. If the dimension sheet does not provide for a specific x-check under the cab, symmetrical rivets, bolts, or holes can be used. On a sport-utility vehicle, the center section is the frame under the passenger compartment. If the legs of the x-check on a full-frame vehicle are more than 6 mm off, diamond damage may be present.

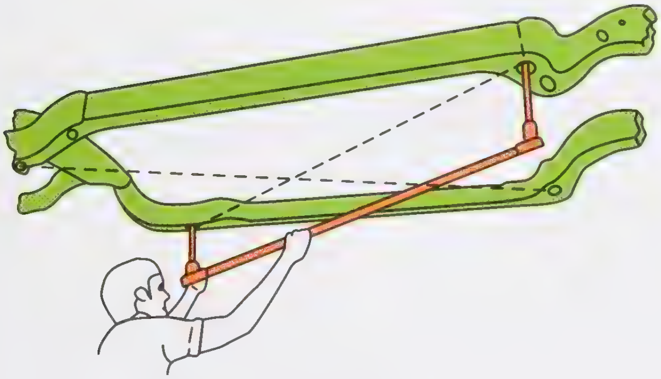


Figure 14-23. *The x-check for diamond is made under the center section of the vehicle. (Chief Automotive Systems)*

Unibody vehicles can be checked for diamond damage by x-checking at the rocker panels. The rocker panels are the boundaries of the center section of a unibody vehicle. Measure from the front of the rocker panel on one side of the vehicle to the rear of the rocker panel on the other side of the vehicle. This dimension will give you one leg of the x-check. To get the other leg of the x-check, measure from the front of the rocker panel on the opposite side of the vehicle to the rear of the rocker panel across from it. Compare these measurements to identify damage. Although diamond damage is possible on a unibody, it is generally so severe that it is not likely to be repaired. Always look for diamond damage before progressing to other gauging operations.

After checking for diamond damage, look at the dimension sheet and find the mounting locations for the two base centerline gauges. The ***base centerline gauges*** determine if damage is present in the center section of the vehicle. One base centerline gauge is hung at the front of the center section and the other base centerline gauge is hung at the rear of the center section. In **Figure 14-24**, the mounting locations are indicated by pyramids. The datum height is listed.

To install the front base gauge, obtain rods that are slightly longer than the datum height measurement. Install the rods and attachments on the gauge. Slip the attachment hook into the hole in the vehicle as specified by the dimension sheet. The attachment hooks should point toward the vehicle's centerline. Set the gauge at the specified datum height (in this example, 152 mm). Use the scale on the rod or measure from the frame down to the bar with a tape measure.

Move the bars either toward or away from centerline so the rods hang perpendicular to the frame. Then tighten down the thumbscrews. In this example, the holes are the same distance from centerline. If the holes are not symmetrical, the gauge bars can be set to compensate. Hang the rear base gauge in the same manner as the front gauge. Check the dimension sheet for datum height and hole location.

Once the base gauges are hung, the center section of the vehicle can be checked for twist. Twist means that the front and rear portions of the center section are not level in relation to each other. See **Figure 14-25**. To read the centerline gauges, stand about 10 feet in front of the vehicle. Sight with both eyes across the top of the base centerline gauges. If the centerline gauges are level to each other, there is no twist. If the gauges are not level, the center section has twist. **Figure 14-26** shows the base centerline gauge reading.

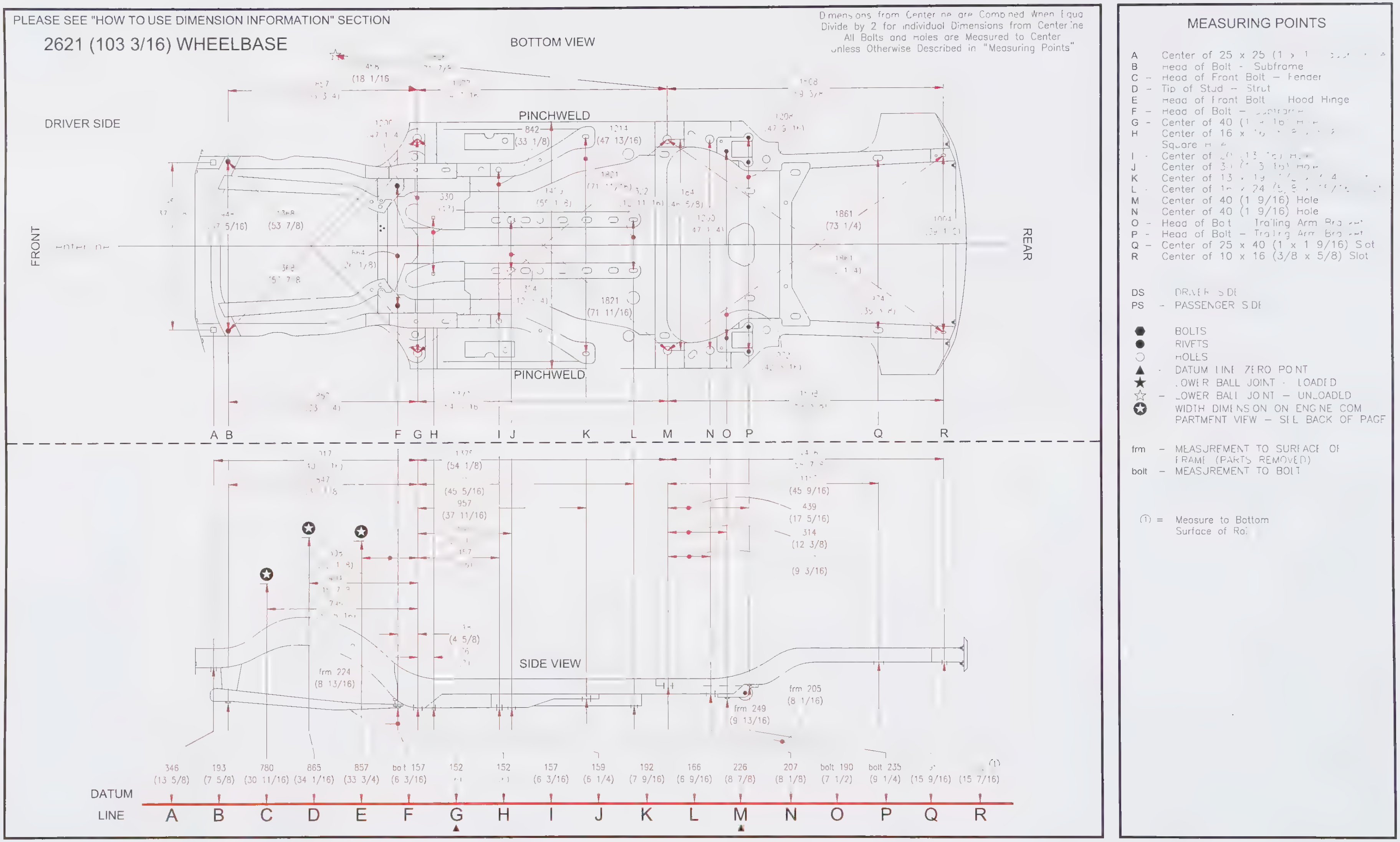

PLEASE SEE "HOW TO USE DIMENSION INFORMATION" SECTION
2621 (103 3/16) WHEELBASE
BOTTOM VIEW
Dimensions from Centerline are Combined When Equal
Divide by 2 for Individual Dimensions from Centerline
All Bolts and Holes are Measured to Center
Unless Otherwise Described in "Measuring Points"
DRIVER SIDE
FRONT
Centerline
REAR
PINCHWELD
PINCHWELD
(18 1/16)
842
(33 1/8)
1214
(47 13/16)
330
1821
(71 11/16)
1861
(73 1/4)
(53 7/8)
(45 5/8)
A B F G H I J K L M N O P Q R
SIDE VIEW
(54 1/8)
(45 5/16)
957
(37 11/16)
(45 9/16)
439
(17 5/16)
314
(12 3/8)
(9 3/16)
(4 5/8)
frm 224
(8 13/16)
frm 249
(9 13/16)
frm 205
(8 1/16)
346 (13 5/8)
193 (7 5/8)
780 (30 11/16)
865 (34 1/16)
857 (33 3/4)
bolt 157 (6 3/16)
152
152
157 (6 3/16)
159 (6 1/4)
192 (7 9/16)
166 (6 9/16)
226 (8 7/8)
207 (8 1/8)
bolt 190 (7 1/2)
bolt 235 (9 1/4)
(15 9/16)
(15 7/16)
DATUM LINE
A B C D E F G H I J K L M N O P Q R
MEASURING POINTS
A Center of 25 x 25 (1 x 1
B Head of Bolt - Subframe
C - Head of Front Bolt - Fender
D - Tip of Stud - Strut
E Head of Front Bolt Hood Hinge
F - Head of Bolt - Subframe
G - Center of 40 (1 9/16) Hole
H Center of 16 x
Square Hole
I - Center of
J Center of 3
K Center of 13 x 19
L - Center of 1 x 24
M Center of 40 (1 9/16) Hole
N Center of 40 (1 9/16) Hole
O - Head of Bolt Trailing Arm Bracket
P - Head of Bolt - Trailing Arm Bracket
Q - Center of 25 x 40 (1 x 1 9/16) Slot
R Center of 10 x 16 (3/8 x 5/8) Slot
DS DRIVER SIDE
PS - PASSENGER SIDE
⬢ BOLTS
● RIVETS
○ HOLES
▲ - DATUM LINE ZERO POINT
★ - LOWER BALL JOINT - LOADED
☆ - LOWER BALL JOINT - UNLOADED
✪ WIDTH DIMENSION ON ENGINE COMPARTMENT VIEW - SEE BACK OF PAGE
frm - MEASUREMENT TO SURFACE OF FRAME (PARTS REMOVED)
bolt - MEASUREMENT TO BOLT
(1) = Measure to Bottom Surface of Rail

Figure 14-24. *The pyramids show where the base gauges should be mounted.*

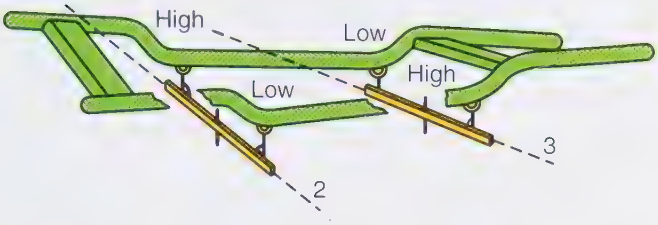


Figure 14-25. *Twist means that the ends of the center section are not level. (Chief Automotive Systems)*

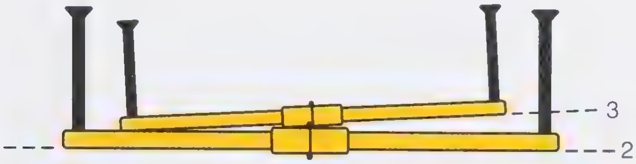


Figure 14-26. *The base gauges, #2 and #3, must be level with each other. If these gauges are not level, twist is present. (Chief Automotive Systems)*

Once the base centerline gauges are read (refer to them as gauges #2 and #3), the front and rear gauges can be hung. Again look at the dimension sheet to find the hole location and datum height. Centerline gauge #1 should be at the front of the vehicle at or near the radiator support. Centerline gauge #4 should be near a rear cross member. If the exhaust system or other obstruction prevents setting the datum at the specified height, the datum can be adjusted. Because datum is a reference only, as long as the same amount is added or subtracted at each gauge, the relative heights of the centerline gauges will not change. For example, if the gauges should be set at the heights shown in **Figure 14-27** but gauge #4 needs 50 mm added for clearance, add 50 mm to all gauges.

When centerline gauge #1 is set, it can be read into gauge #2. As with the base centerline gauges, look across the top of the gauges. Use both eyes. If gauge #1 is not level with gauge #2, there is an out-of-level condition, such as sag or kickup. An out-of-level condition of centerline gauge #1 means that one side of the front of the vehicle is higher than the other. See **Figure 14-28**. If both sides of the front of the vehicle are up (or down) the same amount, there isn't an out-of-level condition. However, because the front is higher than it should be, there is datum misalignment. Hang gauge #4 and check it in the same manner as gauge #1. Then read gauge #4 into gauge #3.

The next step is to check the centerline. At least three centerline pins must be used to check centerline. Lining up only two centerline pins will not provide any useful information. Stand at least ten feet from the vehicle and sight along the centerline pins with one eye. See **Figure 14-29**. If the centerline pins do not line up, as shown in **Figure 14-30**, sideway damage is present.

Gauge Number	Reference Datum Height	Modified Datum Height
1	232 mm	282 mm
2	154 mm	204 mm
3	152 mm	202 mm
4	379 mm	429 mm

Figure 14-27. *Adding 50 mm to each height will allow the gauges to clear obstructions.*

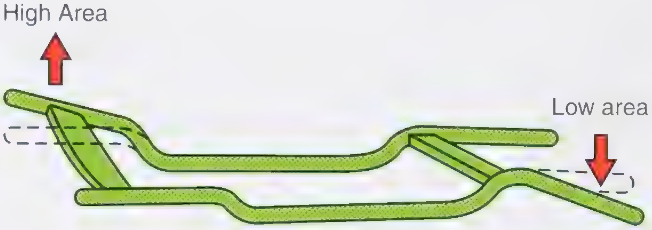


Figure 14-28. *This diagram shows one frame rail higher than the other at the front and one frame rail lower than the other at the rear. (Chief Automotive Systems)*

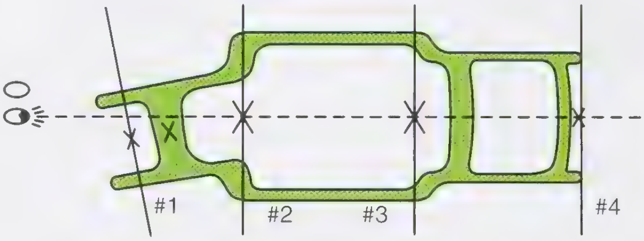


Figure 14-29. *Use one eye to sight along the centerline pins when checking for alignment. (Chief Automotive Systems)*

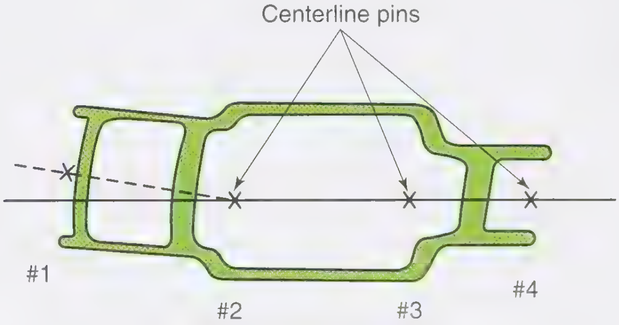


Figure 14-30. *In this diagram, the Xs indicate centerline pins. Gauges 2, 3, and 4 line up while gauge 1 does not. Sideway damage is present. (Chief Automotive Systems)*

Diamond damage may cause the front and rear sections to rotate. This rotation will show up as centerline misalignment—the centerline pins in the center section of the vehicle will not line up with the centerline pins in the front or rear sections.

If a vehicle with out-of-level or twist damage shows centerline pin misalignment, the centerline pin may be off due to the ***pendulum effect***. An out-of-level gauge will cause the centerline pin to be offset. **Figure 14-31** shows the pendulum effect that moves the centerline pin due to improper height of a rail. If the pendulum effect is suspected, simply adjust the gauge so it is level; then check centerline again. If the centerline pins now line up, no sideway is present.

Mash damage will also affect centerline pin alignment. See **Figure 14-32**. Because one rail is shorter than the other, the gauge hung on the short rail will not be square, indicating false centerline misalignment. Measure the length of the damaged rail and compare it to the standard. If the rail has mash damage, the centerline pin misalignment may be due to that problem. Position the mash side of the gauge so that it is perpendicular to the centerline of the vehicle. Then recheck the centerline.

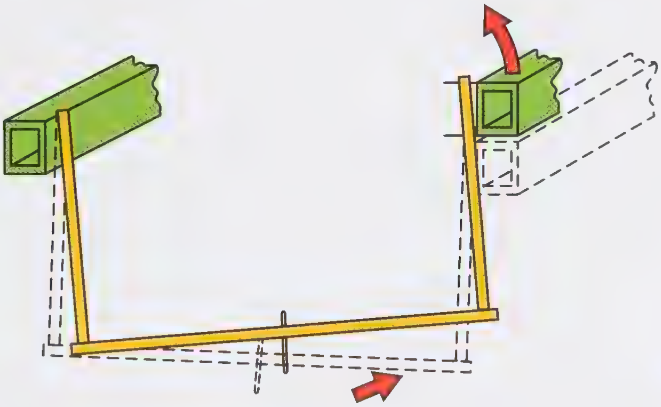


Figure 14-31. *An out-of-level gauge may give a false indication of sidesway. Longer rods make this problem more likely. Level the gauge and check centerline. (Chief Automotive Systems)*

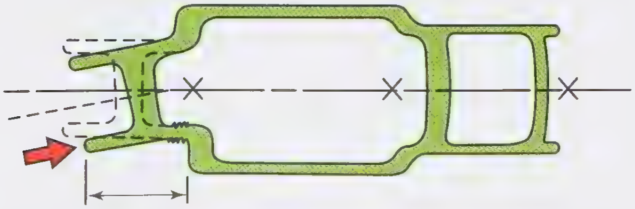


Figure 14-32. *Mash damage will move the centerline to the side of the short rail. (Chief Automotive Systems)*

Strut Tower Gauge

A strut tower gauge is used to check the strut towers for damage. It consists of two horizontal bars and two vertical bars. The horizontal bars are used to establish centerline, and the vertical bars set datum height. Pointers on the upper horizontal bar are set to the width between the measuring points on the strut towers. In most cases, the front wheels must be removed to set the gauge. The upper horizontal bar and the vertical bars are positioned on the vehicle. Once these bars are installed, the lower horizontal bar is installed and set to datum height on the vertical bars. The strut tower gauge is then read into the other gauges. **Figure 14-33** shows a strut tower gauge in use.

Centerline misalignment may be present if the centerline pins do not line up. If the centerline pin on the strut gauge is off, the deviation may be due to the pendulum effect rather than centerline misalignment. If the height of strut towers is not equal, the gauge will hang crooked, causing the centerline pin to be off. As with an out-of-level centerline gauge, if the strut tower gauge is leveled, the centerline pin will line up if there is no centerline misalignment.

Three-Dimensional Measurements

Three-dimensional measurements provide the most accurate damage information. All three dimensions—length, height, and width—are part of the measurement.

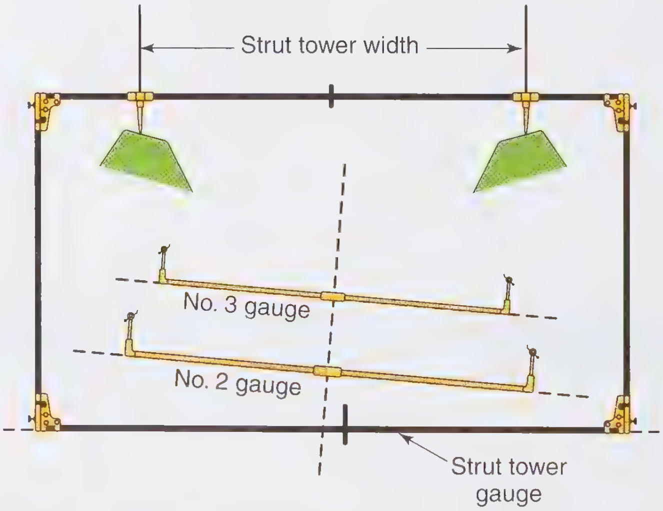


Figure 14-33. *This diagram shows a strut tower gauge used to project the centerline of the towers below the vehicle. The strut tower centerline pin is read into the centerline pins of gauges 2 and 3. (Chief Automotive Systems)*

If misalignment is present, the three-dimensional measurement will indicate which single dimension or combination of dimensions is out of specification.

Measuring Tools for Three-Dimensional Measurements

The equipment used to make three-dimensional measurements on damaged vehicles includes the dedicated bench, universal bench, measuring bridge, laser system, and computer-aided measuring system. Benches are used for unibody vehicles only. All three-dimensional measuring equipment locates measuring points for length, height, and width.

All three-dimensional measuring systems will locate lower body measuring points. On a unibody vehicle, lower body measuring points are structural parts, such as the underside of the radiator support, the lower front unirails, and the rear unirails. On full-frame vehicles, the frame itself is the lower body. Some three-dimensional measuring systems also locate measuring points on the upper body, such as the strut towers, center pillars, or cowl.

Dedicated Bench

When a unibody vehicle is assembled at the factory, the structural parts, such as unirails and pillars, are fixed to jigs for proper positioning. ***Jigs*** hold the parts in the proper position so they can be welded together. In this way, the factory can consistently produce vehicles with the same dimensions. A ***dedicated bench***, shown in **Figure 14-34**, uses jig-like structures called fixtures to identify damage and hold replacement parts in position. The bed of the bench serves as a datum plane.

A dedicated bench can measure the underbody of a unibody vehicle, as well as the upper body strut tower location. The vehicle-specific fixtures are installed in specified locations on the bench. In some types of dedicated benches, the drive train, engine, transaxle, steering, and suspension systems must be removed from the damaged vehicle because the fixtures are positioned where these parts are mounted. The damaged vehicle is raised on a two-post lift, the bench is rolled under the vehicle, and the fixtures are attached. Precise positioning of the bench under the vehicle is critical because the vehicle will be supported by the center section fixtures.

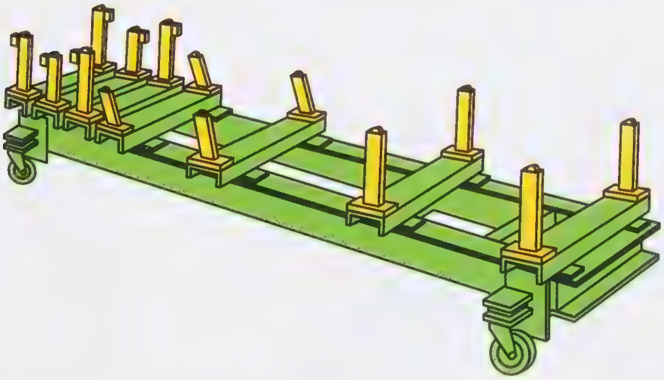


Figure 14-34. *A dedicated bench uses fixtures to identify damage and hold replacement parts in position.*

Damage may prevent the mounting of the vehicle. For example, a collision can move a shock tower inward so the shock tower fixture holds the vehicle out of position, preventing the alignment of the center section fixtures. In this case, the shock tower fixture should be removed so the center section of the vehicle can be mounted.

Once the vehicle is mounted, the alignment between the fixtures and the damaged vehicle can be examined. If the holes in a part, such as the lower frame rail suspension mounting holes, do not line up with the holes in the corresponding fixture, the part is damaged. Parts with holes that line up perfectly are not damaged. The damaged vehicle is held in place for pulling by the pinch weld clamps, not by the fixtures. The fixtures can remain in place during pulling operations if they do not interfere. Once pulls are made and the damage begins to move, fixtures that could not be mounted because of damage can be placed. The fixtures can be used to mount and position replacement parts.

The fixtures for a dedicated bench can be used only on a specific type of vehicle. Therefore, the fixtures for a specific vehicle can usually be rented from a distributor. Once the repair is complete, the fixtures are returned. A dedicated bench is an accurate way to measure and repair a damaged vehicle.

Because using a dedicated bench is a very involved process and computerized measuring systems can be nearly as accurate, dedicated bench systems are not commonly used in body shops. However, some vehicle manufacturers are requiring shops to use a dedicated bench to repair aluminum unibody vehicles.

One dedicated bench manufacturer has designed fixtures with exchangeable ends. This allows one set of fixtures to measure several different types of vehicles by changing only the ends. The replaceable end dedicated bench can also be set up to measure door hinge mounting locations on the upper body.

Universal Bench

A ***universal bench*** is similar to a dedicated bench in that the bed of the bench serves as a datum plane. Also, the vehicle can be tied down to the universal bench and pulls can be made with the vehicle on the bench.

In a universal bench system, the damaged vehicle is mounted on the bench. The manual provided with the bench will specify how the vehicle should be mounted. With some systems, the vehicle is either raised on a lift by the rocker panels or jacked up and set on wheel stands. Then the bench is rolled under the vehicle, and the vehicle is lowered onto the bench. Other systems are assembled under the vehicle. A universal bench is shown in **Figure 14-35**.

The vehicle is mounted at control points. ***Control points*** are holes located in the four corners of the vehicle's center section that will support the weight of the vehicle. Control point mounts will fit into the control points. Control points are different from measuring points, because control points can be used to support the vehicle. Measuring points are used to locate the position of parts.

The control point mounts are set up for proper height, width, and length as specified in the bench manual or set-up sheet. ***Set-up sheets*** list the location of control points and measuring points. Once the vehicle is mounted, various measuring points on the vehicle can be located. These measuring points are on the underbody and in the engine compartment. The upper body measurements are limited to the strut tower and radiator support. A set-up sheet displaying control points and the strut tower measuring points is shown in **Figure 14-36**. The upper diagram shows datum and lists the heights that the control points and the strut tower measuring bar should be set at. The bottom diagram shows the length and width settings for the control points and the strut tower measuring bar.

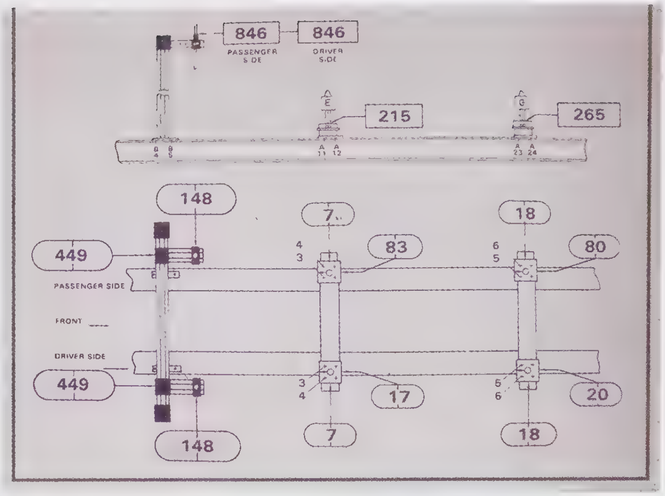


Figure 14-36. *The bar on the left measures strut tower location. The two bars on the right measure control points.*

One type of universal bench measuring system uses a zero plane. For length measurements, a zero plane is established near the rear of the center section. The zero plane is simply a starting point for measurements. Length measurements are taken from the zero plane forward or from the zero plane rearward. See **Figure 14-37**. Height measurements are made from the datum plane formed by the bench. Width measurements are made from centerline.

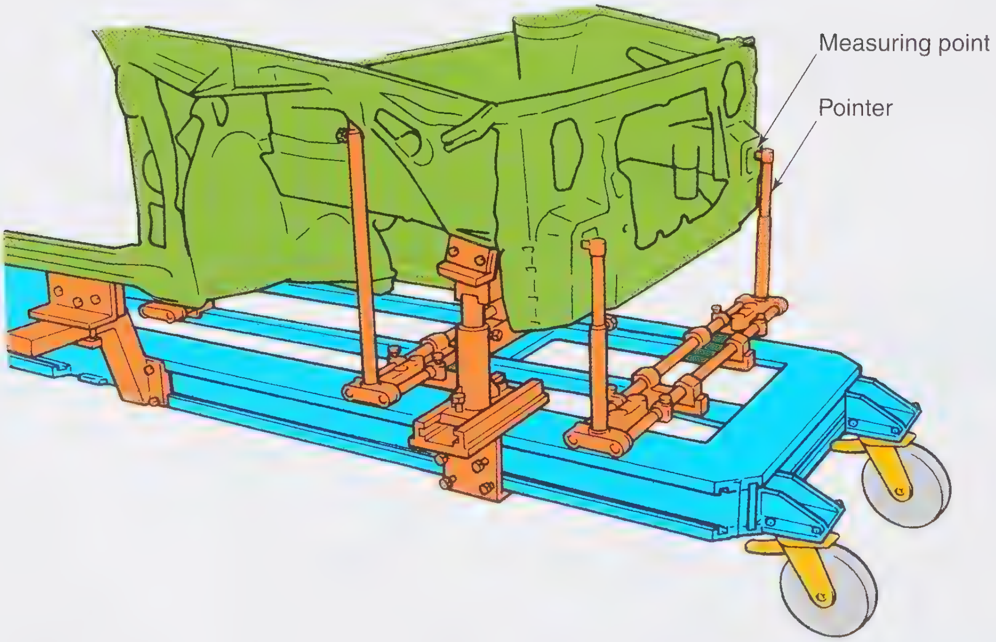


Figure 14-35. *A universal bench uses pointers to locate measuring points.*

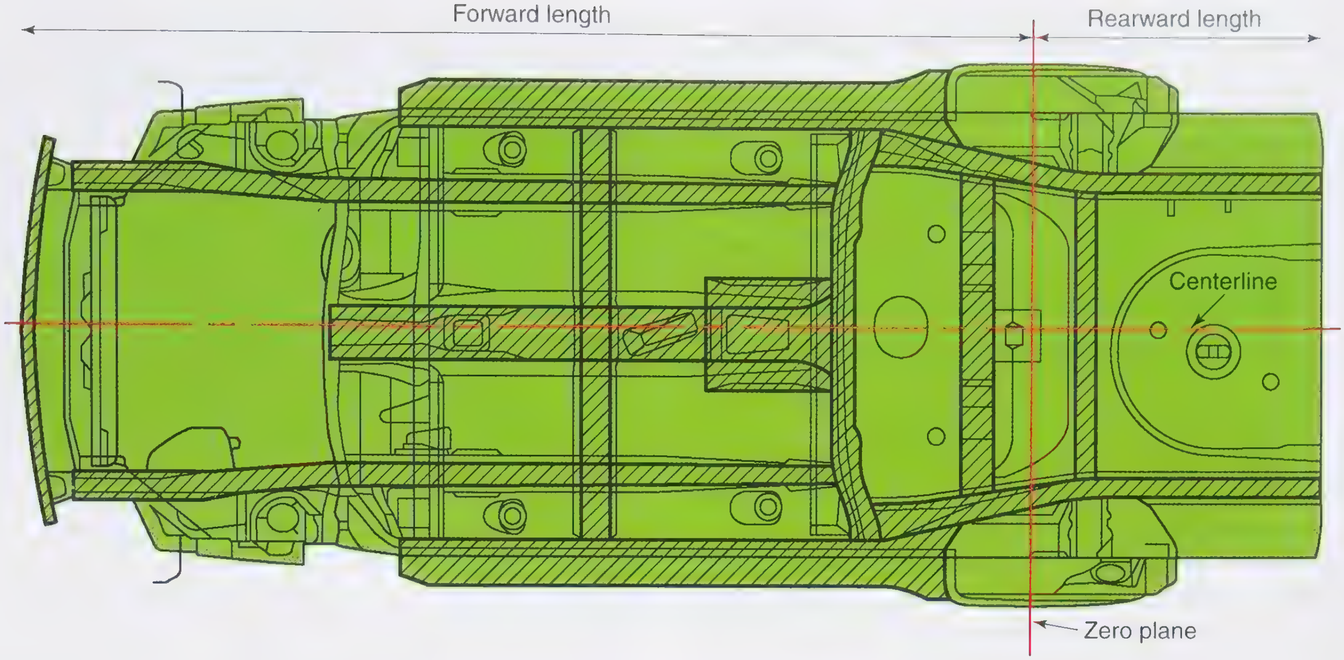

Forward length
Rearward length
Centerline
Zero plane

Figure 14-37. *Length measurements are made from the zero plane.*

Once measuring is completed, the pointers should be lowered or removed while pulling. To check on the progress during pulling, the pointers can be raised. If structural parts must be replaced, the parts can be fitted and checked with the vehicle on the bench. This should take place before any welding. Because a universal bench consists of many parts, careful housekeeping is very important. All parts must be put away after use, because they are easily lost. The universal bench can give an accurate diagnosis of unibody damage. However, universal benches are less commonly used than the computerized measuring systems presented later in this chapter.

Measuring Bridge

A ***measuring bridge***, **Figure 14-38**, is similar to a universal bench in that measuring points are identified and a datum plane is established. However, the vehicle is not mounted on the measuring bridge, and the measuring bridge cannot be used to hold or pull the vehicle.

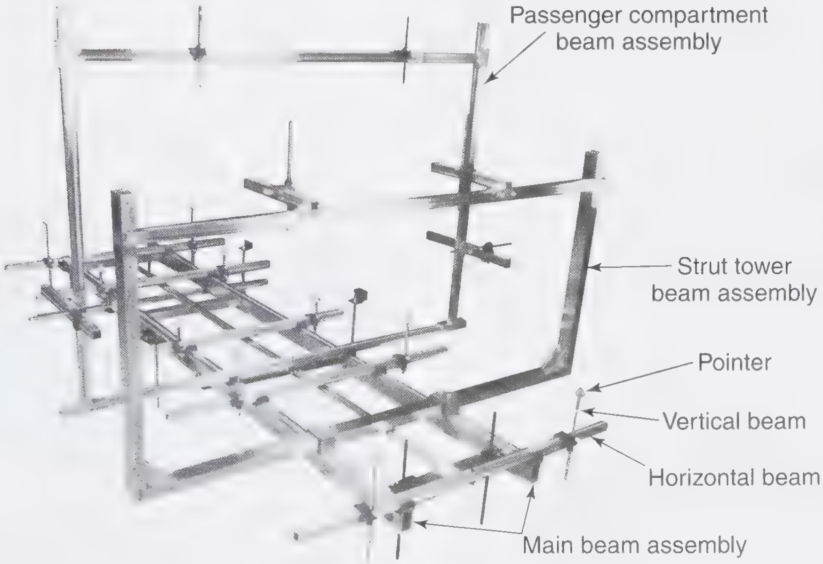

Passenger compartment beam assembly
Strut tower beam assembly
Pointer
Vertical beam
Horizontal beam
Main beam assembly

Figure 14-38. *The measuring bridge can locate measuring points on the underbody and upper body.*

A measuring bridge can be used with some types of frame machines, such as racks or floor pot systems. The vehicle is mounted on the frame machine and then the measuring bridge is rolled or positioned under the vehicle. Both the vehicle and the measuring bridge must be level.

As with a universal bench, four control points are identified in the vehicle's center section. These control points are used as additional measuring points; they cannot be used to mount the vehicle. The beams and pointers are installed at the locations indicated on the set-up sheet. Both upper body and underbody measuring points can be located. The points are located by sliding pointers along beams. The main beam assembly under the vehicle is used to set length, the vertical beams are used to set height, and the horizontal beams are used to set width. With these three dimensions, virtually any point on the vehicle can be located. A beam assembly can also be set up through the door openings to take measurements inside the passenger compartment.

Pointers can locate holes or bolts. Some bridges use only cone-shaped pointers to locate holes or bolts. More complicated systems use an array of cone-shaped pointers to locate various sizes of holes and recessed pointers to fit over various sizes of bolt heads. The pointers should be dropped out of the way when pulling the damage. The measuring bridge can also be used to verify the location of replacement parts before welding.

Laser Measuring System

A ***laser measuring system*** relies on a beam of light to form a straight line from the laser emitter to the target. It must be positioned so it points to exactly what it is intended to measure. The mounting of the laser emitter is critical. Both underbody and upper body measurements are possible with the laser system.

To make underbody measurements of centerline, a system of rods is assembled under the vehicle's center section to make a square that supports the laser emitter. These rods are attached by adapters to holes in the unibody or the pinch welds. If the adapters will be placed into holes, the holes must be symmetrical left to right. Measure equal distances from the end of the rocker panels, if the adapters will be installed on the pinch welds.

The laser emitter mounted on the square under the center of the vehicle establishes a centerline. Specification measurements can be taken with a tram from the centerline to identify misalignment. Two lasers, one on each side of the vehicle, can be mounted on the center square for comparison measurements of the upper body. For example, if one center pillar is pushed in from a side impact and the opposite center pillar is undamaged, measurements from the laser on the damaged side can be compared to measurements from the laser on the undamaged side. The damaged center pillar is pulled until the two measurements are equal.

Additional upper body measurements are possible with a laser mounted above the hood opening. With the hood removed, rods are attached to the center square to form a bridge above the engine compartment, close to the windshield. A laser is mounted on the bridge to identify centerline in the engine compartment. See **Figure 14-39**. Specification measurements from the centerline will locate misalignment.

A ***comparative laser*** compares an undamaged side of the vehicle with the damaged side. The comparative laser is a telescoping tube with a laser emitter at each end. The tube is mounted to pinch welds on opposite sides of the vehicle, perpendicular to centerline. Pulling out on one end of the telescoping tube causes the other end to move out exactly the same amount. This system only works if one side of the vehicle is undamaged. For example, if the passenger side A pillar is damaged and the driver's side is not, the telescoping tube is mounted on the pinch welds in the door opening, near the roof. The telescoping tube is pulled out so the laser points to the door hinge mounting surface or another measuring point on the driver's side. The laser on the passenger side will point to the same location on the damaged side of the vehicle. The damaged A pillar can be straightened until the laser indicates that the pillar is in the correct location. This system will also help position replacement panels prior to welding. See **Figure 14-40**.

The clear plastic ruler shown in **Figure 14-41** is also used for comparative measurements. Magnets attach plastic rulers to similar points on opposite sides of the vehicle. The laser points to the exact location on both sides of the vehicle. The plastic rulers must be level and located exactly opposite each other for this system to work. The telescoping tube can be mounted to the rocker panel pinch welds to compare measuring points, such as the location of the front suspension ball joints.

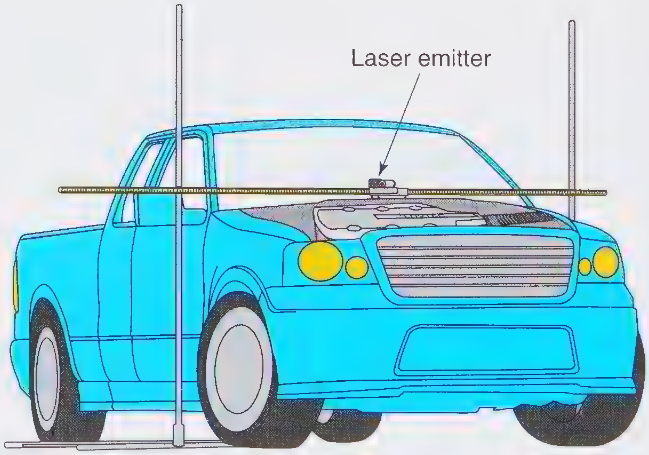


Figure 14-39. *This specification laser system can identify the centerline of the underbody, as well as the centerline of the engine compartment.*

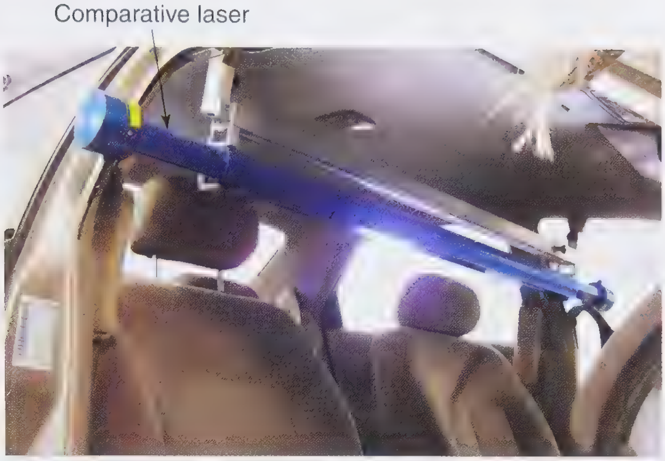


Figure 14-40. *The comparative laser unit is mounted on the pinch weld in the upper door opening.*

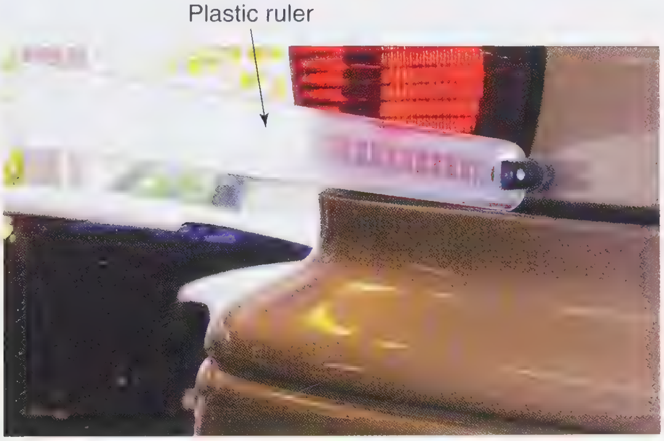


Figure 14-41. *Targets can be positioned on the vehicle to locate measuring points.*

Computer-Aided Measuring System

Computer-aided measuring systems locate damage by comparing vehicle dimension standards stored by the computer with measurements obtained from the vehicle. All computer-aided measuring systems share the following features:

- Computer—Stores vehicle dimension standards and calculates the difference between the standard and actual vehicle measurements.
- Keyboard—Used to enter vehicle information (year, model, make, type) as well as commands.
- Monitor—Displays the vehicle dimensions, as well as the measuring points and the actual vehicle measurements. The displays will walk the technician through the set up and use of the system.
- Printer—Used to make a printout of the monitor's display.

Computer-aided measuring systems are designed to be user-friendly. Only basic computer skills are required to operate these systems. The monitor will display instructions on how to set up and calibrate the system. Once the vehicle data is entered into the computer the monitor will display various measuring points. Computerized measuring systems rely on some type of device, a probe or a pointer, to inform the computer of the location of a measuring point. The measuring data is either entered into the computer by the technician or sent to the computer by the devices attached to the measuring points.

To calibrate the system, the technician selects undamaged measuring points and follows the on-screen instructions to measure them. The computer uses these undamaged measuring points as a reference to calculate the correct position of all the other measuring points. Once the system is calibrated, any measuring point located by the system will be described by deviation from the height, width, and length of the standard. Computer-aided measuring systems can be very accurate, but they are no more accurate than the information supplied to them. Carefully follow the directions for set up and use. An error in calibration will lead to inaccurate measurements.

Figure 14-42 shows the computer, monitor, printer, and keyboard. As previously mentioned, these components are found on all computer-aided measuring systems. However, the way these measurements are obtained varies. Computer-aided measuring systems may use measuring arms, ultrasound, lasers, or trams to locate measuring points.

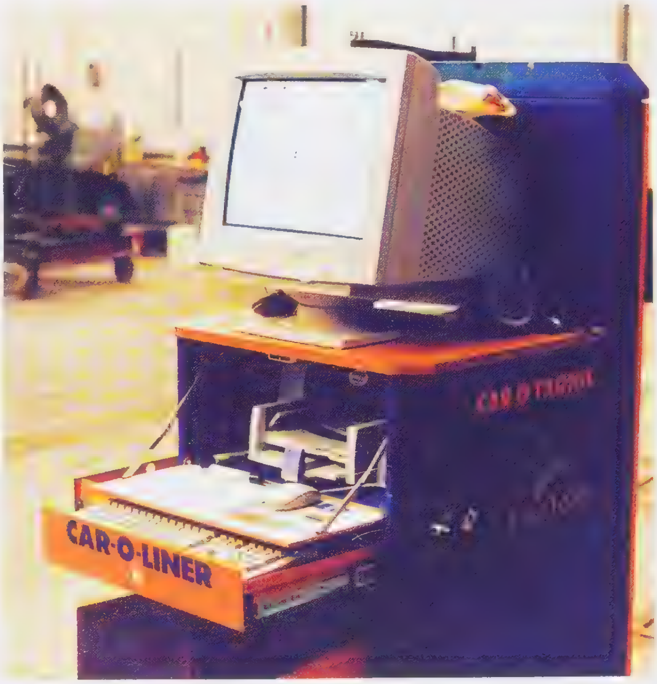


Figure 14-42. *This computer-aided measuring system can be rolled around the shop to be near the damage.*

Measuring Arm Systems

A ***measuring arm*** is shown in **Figure 14-43**. The arm slides on a track located under the vehicle. The arm can be used to locate underbody and upper body measuring points. Specified attachments are placed on the arm. The attachments are designed to fit onto or into the measuring points. When the arm is in position, the technician pushes a button on the arm or hits a key on the keyboard. The location of the measuring point is determined by the orientation of the arm. The computer calculates and then displays any difference between the actual location of the measuring point and the standard. The location is given as a difference in the height, width, and length. When additional measuring points are located with the arm, a clear view of the damage is possible. A measuring arm in use, with an offset attachment to clear a spring shackle, is shown in **Figure 14-44**.

Upper body measurements can be taken by adding a calibrated extension and cross bar to the measuring arm. The computer monitor will list upper body measuring points and the calibration values that must be set on the extension and cross bar. **Figure 14-45** shows a measuring arm, extension, and cross bar setup being used to measure the location of a mounting bolt on a radiator support. The accuracy of the measurement depends on the rigidity of the measuring arm, extension, and cross bar. If the measuring arm, extension, or cross bar move, tip, or wobble, the measurement will not be accurate. Make sure all connections are tight so the apparatus does not wobble. If there is not a standard stored in the computer for a specific measuring point, such as a full-frame upper body dimension, measurements can be taken on the undamaged side and compared to those from the damaged side.

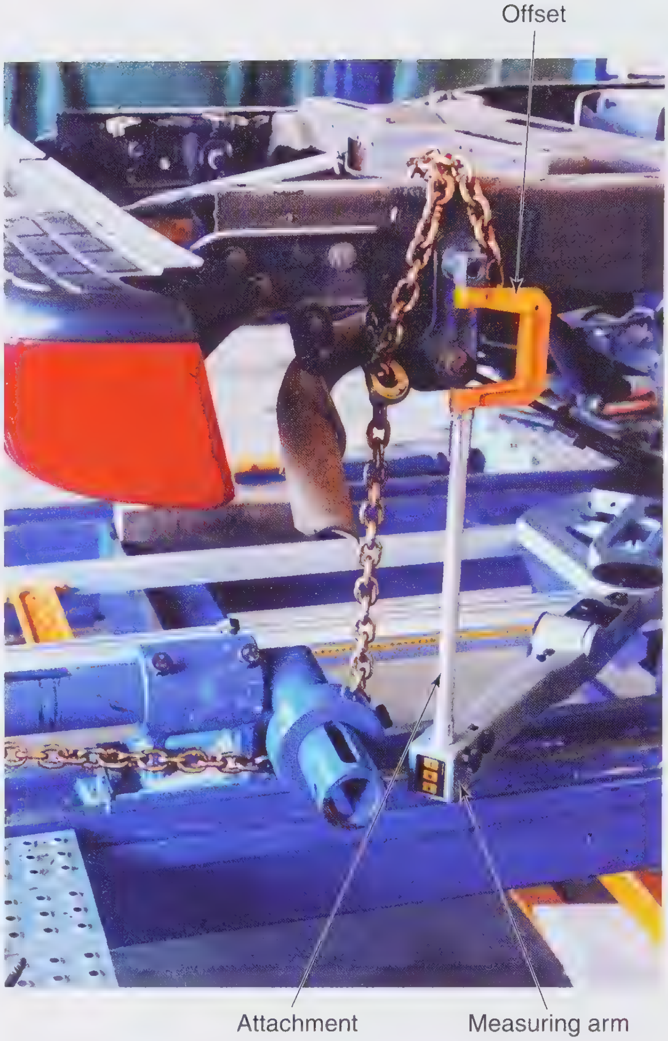


Figure 14-44. *This attachment allows the measuring arm to reach around obstructions.*

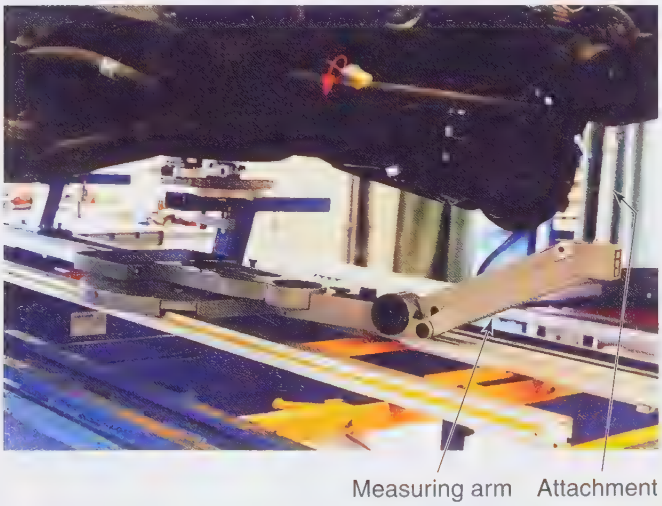


Figure 14-43. *This measuring arm slides on a bridge beneath the vehicle. The pointer is positioned in the measuring hole.*

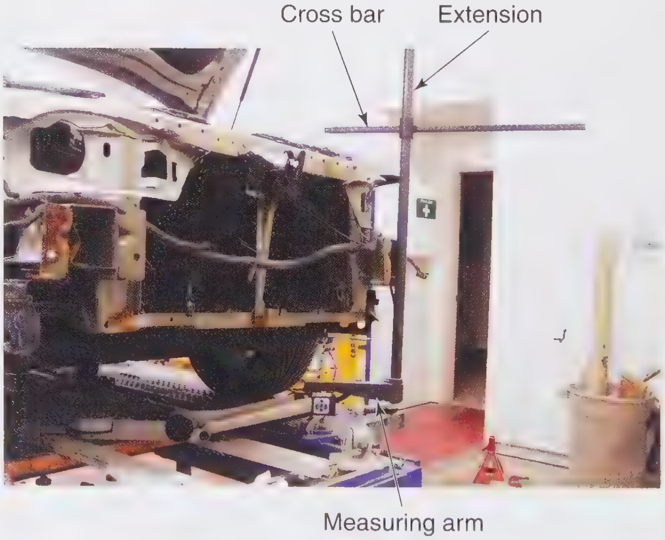


Figure 14-45. *An extension and a cross bar are added to the measuring arm to reach upper body measuring points.*

This system also has a feature to aid in pulling the damaged components to the proper location. The technician selects a monitor screen that displays the proper location of the measuring point in a bull's eye. The location of the misaligned measuring point is also indicated on the screen. Pulling the damaged component closer to the proper location moves the measuring point on the screen closer to the bull's eye. When the measuring point is in the bull's eye, the damaged component is in the proper location.

Ultrasound Measuring System

An ultrasound measuring system uses ultrasound technology to locate vehicle measuring points. As with other systems, three undamaged points are needed for calibration. The system, shown in **Figure 14-46**, consists of an under-vehicle data beam, attachment accessories, and probes.

Specific attachment accessories are installed at the measuring points according to instructions presented on the computer monitor. As with other systems, a picture of the measuring point on the computer screen shows where to attach the accessories. Next, a probe is hooked up to each accessory. The probe contains a wire that is connected to the data beam. The probe sends signals to microphones in the data beam. The data beam sends information on the measuring point location to the computer. Up to twelve measuring points can be located at one time. The location of each measuring point will be displayed on the monitor. If the measuring point is not at the specified location, the deviation—the amount that a measuring point is out of specification—will be indicated on the monitor. The deviation of each measuring point from the length, width, and height specification will be listed. Upper body measurements can be obtained with the long attachments. This system also displays possible pull location and direction.

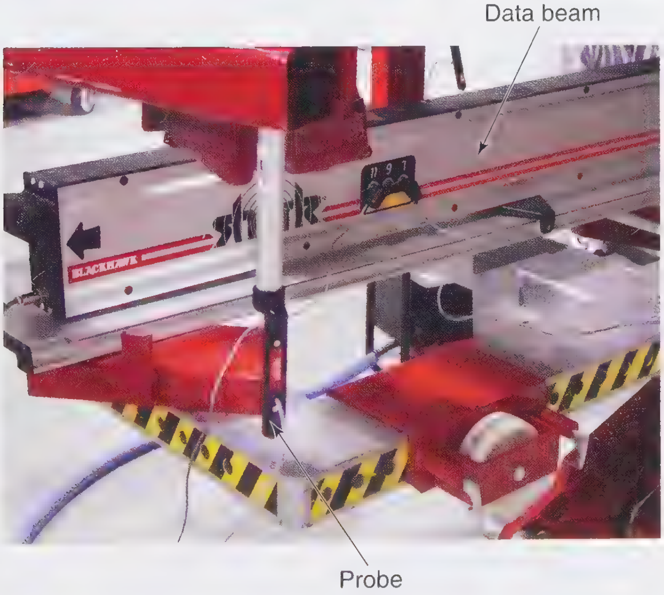


Figure 14-46. *The ultrasound data beam is set up beneath the vehicle. Probes are attached to measuring points with accessories.*

Laser Measuring System

The next type of measuring system uses a laser beam. A laser beam is a thin beam of light that is very intense and can travel substantial distances without diffusing. In this system, the laser beam is emitted by an under-vehicle scanner. Reflective targets are placed at specified measuring points on the vehicle. See **Figure 14-47**. The laser beam is reflected off the targets and detected by the scanner. The scanner sends information on the position of each target to the computer. The computer uses triangulation to determine location of each target and the deviation from standard. The information is displayed on the monitor.

To use a laser system, the scanner is set into a tray under the center section of the vehicle. The cable connecting the scanner to the computer must be on the left side of the vehicle. Vehicle information is entered into the computer. The computer monitor displays measuring points on the underside of the vehicle. A photo of each measuring point is also displayed on the computer screen. See **Figure 14-48**.

Targets are available in various lengths. The targets are numbered for ease of identification. Targets 1–40 are for general-purpose measuring. Targets 41–45 have special functions.

The computer lists suggested target numbers, selected by the length of the target, for each measuring point. The targets must hang under the vehicle to be seen by the laser.

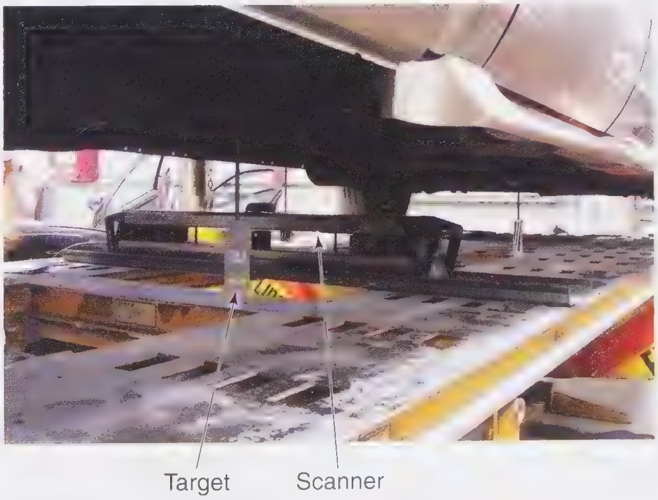


Figure 14-47. *The scanner emits a laser beam that hits various targets.*

Figure 14-48. *The computer screen displays measuring points.*

This makes some upper body measurements difficult. Because the targets hang, a breeze in the shop may cause them to misalign.

The targets are attached to the vehicle at holes, surfaces, bolt heads, or bolt threads. The targets can also be attached to the vehicle with target bases. ***Target bases*** can be magnetic bases that attach to bolt heads or holes, clips that attach to bolt heads, threaded attachments that fasten to protruding bolts, or snap-in attachments that connect to aluminum components. Long, short, and C-shaped extensions are used to position the targets around obstructions, such as the exhaust system or the rear suspension parts.

The system is calibrated by choosing three undamaged measuring points. The scanner sends out laser light to the targets. The laser light is reflected off the targets, and the scanner detects the reflected light. The target position information is sent to the computer. The computer uses the target number and position to determine the deviation of each target from the standard. Upper body measurements, such as the strut tower or fender bolt location, are possible with a system of horizontal bars and vertical scales. The horizontal bars and vertical scales are set to specified width and height. Target numbers 43–45 are hung on the lower horizontal bar so the under-vehicle scanner can read them. The upper body targets indicate length, width, or height of the measuring points.

Computer-Aided Tram

A computer-aided tram uses a telescoping tram gauge and various attachments to locate measuring points on a vehicle. The telescoping tram has an adjustable height rod at one end and an adjustable pointer at the other end. The vehicle information is entered into the computer. The computer screen will display several vehicle measuring points.

On one type of system, the technician must first measure the center section of the vehicle for level by placing the tram, which has a built-in level, on the bottom of the left and right rocker panels at the front of the center section. The measurement is repeated at the rear of the center section. The vehicle must be within 10 mm of level to continue with measurements.

Next the technician selects two measuring points from the computer screen to calibrate the tram. The measuring points must be undamaged and on the passenger's side of the vehicle. A datum rod of the selected length is inserted into one end of the tram. A magnetic head is snapped on the datum rod. The technician enters the datum rod length into the computer, and the computer calculates the height setting for the height rod that will be inserted into the opposite end of the tram, as well as the type of tip that should be placed on the height rod. The tram is set in place under the vehicle. To complete the calibration, the roller button on the tram level is turned to position the bubble in the level to the center.

NOTE

Take note of which end of the tram level is pointing toward the front of the vehicle. Keep the tram level pointed in the same way for all length measurements. The orientation of the tram level is critical.

The tram can measure length and height, as well as perform cross checks. To measure length, the technician selects two points on the same side of the vehicle. The computer will indicate what type of tip should be installed on the height rod and the height at which to set the height rod. Positioning the tram in the measuring points will make a length measurement, which will be displayed at the end of the tram. See **Figure 14-49**. This length measurement is entered into the computer by the technician.

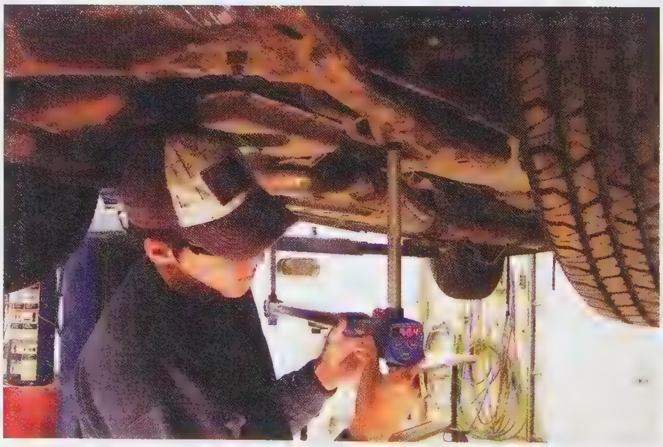


Figure 14-49. *The cross check value is displayed at the end of the computer-aided tram.*

To measure height, the height rod is moved up or down until the bubble level is centered. The height value is entered into the computer by the technician. Cross checks are also listed on the computer screen. Cross checks cannot make height measurements.

In another type of system, the technician selects up to ten measuring points from those displayed on the computer screen. A body zero line will be indicated on the computer screen. The body zero line is in the center section of the vehicle, and all length measurements are indicated from the body zero line. The digital readout on the tram indicates the difference between specified and actual measuring points. The tram sends this information to the computer.

Damage Diagram

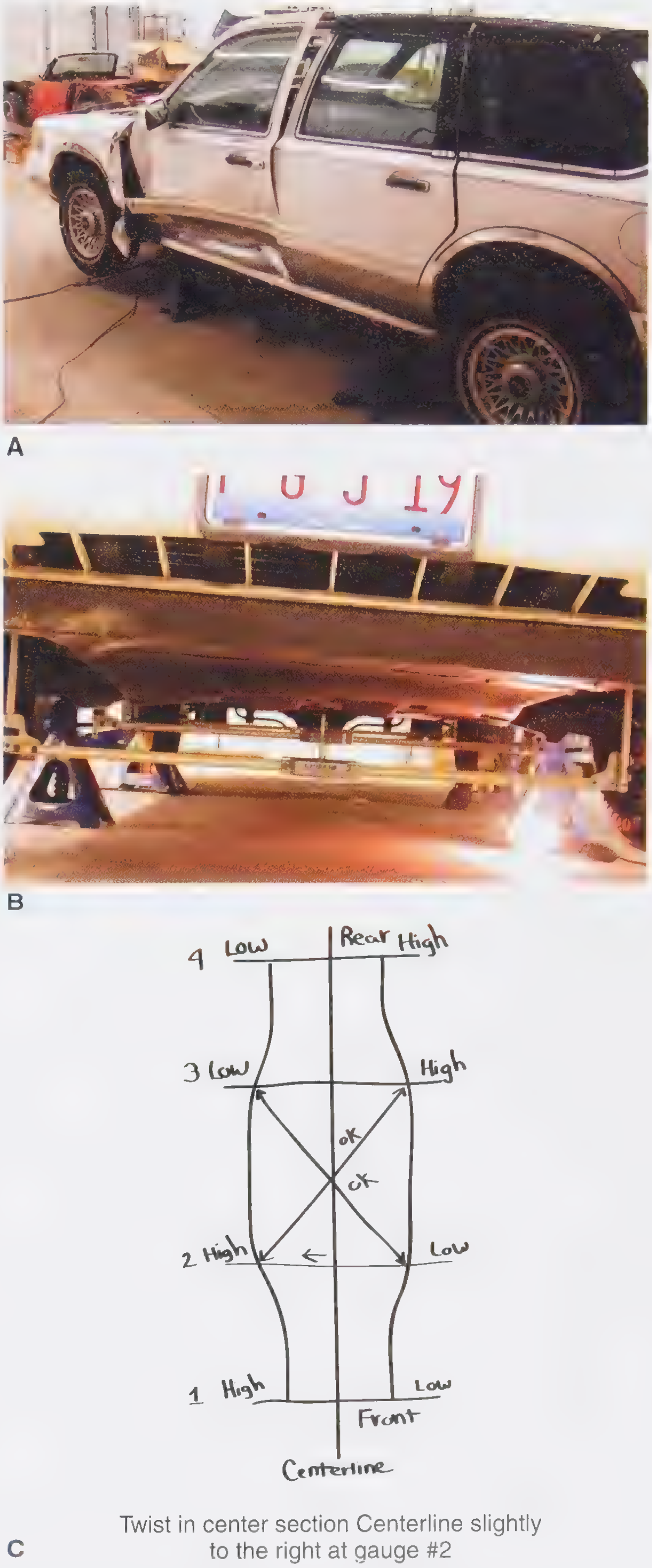
A damage diagram should be made once measurements are complete. A ***damage diagram*** is a sketch that shows where damage or misalignment is found on a vehicle. The diagram can be used to develop a repair plan. Simply looking at a damaged vehicle to figure out how to repair structural damage is often too complicated. Using a damage diagram helps simplify this process.

Make a damage diagram by drawing three boxes representing the front, center, and rear sections of the vehicle. Write in any x-checks that were made. Draw lines to represent gauges 1, 2, 3, and 4. If twist is present, indicate which side of gauges 2 and 3 are low or high. If sag or kickup is present, indicate which side of gauge 1 or 4 is high or low. If sidesway is present, indicate on which gauges the centerline is off. Use the damage diagram as a blueprint for the repair. **Figure 14-50** shows a damage diagram made from information obtained from tram measurements and centerline gauging.

Damage diagrams do not need to be drawn when using computerized measuring systems because the printout of the computer screen shows all the measurements. The printout serves as a blueprint for the repair.

Summary

- Linear measurements are straight-line distances between specified points on a vehicle. There are four types of linear measurements that can be taken on a vehicle: width, height, length, and x-checks.
- Width is the distance from a point to the vehicle's centerline. The centerline is an imaginary plane that runs down the center of a vehicle.
- Height is the distance of a point above datum. Datum is an imaginary plane underneath the vehicle.



Twist in center section Centerline slightly to the right at gauge #2

Figure 14-50. *A—This full-frame vehicle was hit in the left cowl, causing twist. B—The centerline gauges hanging under this vehicle show twist. C—The information obtained from reading the gauges is used to draw a diagram of the damage. The damage diagram indicates the twist.*

- Length is the distance between two points measured parallel to the centerline.
- An x-check is a pair of linear measurements that are compared to each other. The x-check will determine if the measured area is square. If it is square, the legs of the “x” will be equal in length.
- One-dimensional measurements are measurements taken between two points.
- Tolerance is the maximum allowable deviation from the standard. On a full-frame vehicle, the tolerance is 1/4" (6 mm). On unibody vehicles, the tolerance is 1/8" (3 mm).
- Tape measures and trams are used to make one-dimensional measurements.
- Two-dimensional measurements use height and width dimensions to locate a measuring point. Making two-dimensional measurements of a vehicle is referred to as gauging.
- A centerline gauge consists of two horizontal bars, a centerline pin, two rods, and two rod attachments.
- A strut tower gauge is used with centerline gauges on unibody vehicles. The strut tower gauge projects the alignment of the strut towers to the underside of the vehicle, so it can be compared with the centerline gauges.
- The base centerline gauges determine if damage is present in the center section of the vehicle. One base centerline gauge is hung at the front of the center section and the other base centerline gauge is hung at the rear of the center section.
- Diamond damage may cause the front and rear sections to rotate. This rotation will show up as centerline misalignment—the centerline pins in the center section of the vehicle will not line up with the centerline pins in the front or rear sections.
- If a vehicle with out-of-level or twist damage shows centerline pin misalignment, the centerline pin may be off due to the pendulum effect.
- Three-dimensional measurements provide the most accurate damage information. All three dimensions—length, height, and width—are part of the measurement.
- The equipment used to make three-dimensional measurements on damaged vehicles includes the dedicated bench, universal bench, measuring bridge, laser systems, and computer-aided measuring system.
- A dedicated bench uses jig-like structures called fixtures to identify damage and hold replacement parts in position.
- A universal bench is similar to a dedicated bench in that the bed of the bench serves as a datum plane.
- A vehicle is not mounted on the measuring bridge, and the measuring bridge cannot be used to hold or pull the vehicle.
- A laser measuring system relies on a beam of light to form a straight line from the laser emitter to the target.
- Computer-aided measuring systems locate damage by comparing vehicle dimension standards stored by the computer with measurements obtained from the vehicle.
- Computer-aided measuring systems may use measuring arms, ultrasound, lasers, or trams to locate measuring points.
- A damage diagram is a sketch that shows where damage or misalignment is found on a vehicle. The diagram can be used to develop a repair plan.

Review Questions

Please do not write in this textbook. Place your answers on a separate sheet of paper.

1. Width is the distance of a point from the vehicle’s ______.
2. Define *datum.*
3. To determine if damage is present, linear measurements are compared to a(n) ______.
4. What is the difference between symmetrical measuring points and asymmetrical measuring points?
5. Width, length, and height are also known as ______.
6. A unibody vehicle has a frame rail length measurement of 1203 mm. The standard is 1200 mm. Is the frame rail length within tolerance?
7. The tolerance for an x-check is ______ that of a linear measurement.
8. The datum distance between two points is always the same as the point-to-point distance. True or False?
9. Centerline gauges are used to check ______ measurements.
10. Unibody vehicles should always be gauged with the suspension loaded. True or False?
11. Performing an x-check in the center section of the vehicle will locate ______ damage.
12. Where should the base centerline gauges be hung?
13. If centerline gauges #2 and #3 are not level to each other, the damage indicated is ______.
14. Centerline gauge #4 is hung near a rear ______.
15. The most accurate way to locate damage is with ______ measurements.
16. What parts must often need to be removed when mounting a vehicle on a dedicated bench?
17. On one type of universal bench, the zero plane is used to measure ______.
18. A vehicle should be tied down to the measuring bridge during pulling operations. True or False?
19. To set up a computer-aided measuring system, ______ undamaged points are needed for reference.
20. A(n) ______ is a sketch that shows where damage is found on a vehicle.

ASE-Type Questions

1. Two measuring points on opposite sides of a vehicle are not the same distance from centerline. The points are ______.
   (A) symmetrical
   (B) asymmetrical
   (C) control points
   (D) datum points
2. A damaged vehicle is being evaluated. Technician A wants to use a dimension sheet as a standard of comparison. Technician B wants to use a similar vehicle as a standard of comparison. Who is right?
   (A) A only.
   (B) B only.
   (C) Both A and B.
   (D) Neither A nor B.
3. A door opening is the only damaged portion of a vehicle. Technician A wants to measure the opposite door opening and compare it to the damaged door opening. Technician B wants to measure the damaged door opening and compare it to a dimension sheet. Who is right?
   (A) A only.
   (B) B only.
   (C) Both A and B.
   (D) Neither A nor B.
4. Technician A says that datum length measurements can be made with a tram bar. Technician B says that tolerance on a unibody vehicle is plus or minus 6 mm. Who is right?
   (A) A only.
   (B) B only.
   (C) Both A and B.
   (D) Neither A nor B.
5. Which of the following is not an x-check?
   (A) Check for diamond damage under a pickup truck cab.
   (B) Checking the distance between the left and right shock towers.
   (C) Checking for roof misalignment from inside the passenger's compartment.
   (D) Checking for pillar misalignment from inside the passenger's compartment.
6. A tape measure can be used to measure ______.
   (A) length
   (B) width
   (C) height
   (D) All of the above.
7. Which of the following is used to make a linear measurement?
   (A) Self-centering gauges.
   (B) Fixtures.
   (C) A universal bench.
   (D) A tram.
8. A datum distance is measured with a tram. Technician A wants to measure the distance between the ends of the pointers. Technician B wants to measure the distance between the base of the pointers. Who is right?
   (A) A only.
   (B) B only.
   (C) Both A and B.
   (D) Neither A nor B.
9. Centerline gauges make ______.
   (A) one-dimensional measurements
   (B) two-dimensional measurements
   (C) three-dimensional measurements
   (D) four-dimensional measurements
10. A full frame vehicle is damaged. Technician A wants to x-check under the center section first. Technician B wants to hang a centerline gauge under the radiator support first. Who is right?
   (A) A only.
   (B) B only.
   (C) Both A and B.
   (D) Neither A nor B.
11. The base centerline gauges are to be hung on a vehicle. Technician A wants to hang the base centerline gauges before any other gauges. Technician B wants to hang the base centerline gauges last, after all the other centerline gauges. Who is right?
   (A) A only.
   (B) B only.
   (C) Both A and B.
   (D) Neither A nor B.
12. Centerline gauge #1 is not level when compared to centerline gauge #2. The damage indicated is ______.
   (A) mash
   (B) diamond
   (C) sag
   (D) twist
13. In order to clear obstructions on a vehicle, one centerline gauge must be set 100 mm lower than the other gauges. Technician A wants to subtract 100 mm from each centerline gauge height to set datum. Technician B wants to add 100 mm to each centerline gauge height to set datum. Who is right?
   (A) A only.
   (B) B only.
   (C) Both A and B.
   (D) Neither A nor B.
14. The minimum number of centerline gauges needed to check centerline is ______.
   (A) one
   (B) two
   (C) three
   (D) four

15. All of the following are 3-D measuring devices EXCEPT:
    (A) centerline gauges.
    (B) a universal bench.
    (C) a dedicated bench.
    (D) computer-aided measurements.
16. Technician A says that the bed of a dedicated bench serves as the datum plane. Technician B says that the bed of a dedicated bench is used to mount fixtures. Who is right?
    (A) A only.
    (B) B only.
    (C) Both A and B.
    (D) Neither A nor B.
17. A universal bench uses ______ to locate measuring points.
    (A) pointers
    (B) fixtures
    (C) gauges
    (D) trams
18. Technician A says that a measuring bridge can be used to pull a vehicle. Technician B says that centerline gauges make 3-D measurements. Who is right?
    (A) A only.
    (B) B only.
    (C) Both A and B.
    (D) Neither A nor B.
19. When using a computer-aided measuring system, how many undamaged control points are needed to calibrate the system?
    (A) One.
    (B) Two.
    (C) Three.
    (D) Four.
20. In a computer-aided measuring system, which of the following sends out a laser beam?
    (A) Monitor.
    (B) Target
    (C) Scanner.
    (D) Computer.

Chapter 15

Unibody Straightening

Objectives

After studying this chapter, you will be able to:

- Identify unibody damage and compare measurements to standards.
- Explain why the unibody must be straightened before structural parts are removed.
- Describe the importance of multiple pulls.
- Identify where to make tie-downs on a unibody.
- Demonstrate how to make hookups on a unibody.
- Describe the different types of pulls.
- Remove various types of unibody damage.
- Relieve stress in a damaged unibody.

Technical Terms

access window
angle pull
blocking
combination pull
double stretch pull
downward pull
forward pull
heat crayon
infrared thermometer
multiple pull
obvious damage
overpulling
pinch weld clamps
settle back
side pull
spring hammering
stress relief
subtle damage
tie-downs
upward pull

Introduction

This chapter describes the procedures for straightening unibody damage. When repairing a damaged unibody vehicle, the unibody is straightened after the vehicle is measured. After the unibody is straightened, the non-repairable damaged parts are removed and replaced. This is an important aspect of unibody repair. The damaged structural parts, even if they will be replaced, must be straightened to within 1/8" (3 mm) of factory specifications.

Structural parts may be made from high-strength steel. High-strength steel parts require special handling during repair. Kinked high-strength steel parts must be replaced because kinks weaken the grain structure of the steel.

After structural parts of a damaged unibody vehicle have been repaired or replaced, the exterior panels, such as fenders and doors, are installed. Damaged mechanical parts may also be replaced at this time. Once the body and mechanical repairs are made, the vehicle is ready for repainting.

Unibody straightening involves the gradual removal of many small stresses in the damaged unirails or structural parts. To better understand unibody repair, try this demonstration. Start with two pieces of paper that are the same size. Crumple one piece of paper into a ball. Then unfold the crumpled paper and place it on top of the undamaged piece of paper. Notice how the crumpled piece of paper is smaller than the undamaged piece. The crumpled piece can be made larger by straightening each crease. Each crease holds a small part of the paper out of place. By straightening each crease, the dimensions of the crumpled paper can be restored. This is the basic idea behind unibody repair. The proper dimensions of damaged structural parts are restored by carefully releasing all the creases or stresses in the damaged panel.

Because a unibody is designed to absorb collision energy, slight distortion may be found in areas far from the impact. These distorted areas must be pulled back into proper alignment. This is done by holding the unibody in place, attaching clamps in the impact area or other damaged area, and pulling. By pulling the damaged parts into alignment, all the panels welded to the damaged part will also be aligned.

Basic Unibody Straightening Operations

The sequence of operations that should be followed when repairing a damaged unibody vehicle is as follows:

1. Tear down—Remove bolted parts that are in the way of the repair.
2. Identify damage—Locate and identify damage and draw a damage diagram.
3. Plan—Using the damage diagram, plan the repair.
4. Tie-down—Use tie-downs to hold a vehicle in place during pulling and pushing.
5. Hook up—Attach the pull to the vehicle.
6. Straighten—Make pulls to correct the damage.
7. Stress relieve—Use spring hammering or heat to relieve stresses in damaged areas.

The following sections detail each of these basic operations.

Tear Down

Unibody repair requires direct access to structural parts in order to find all the damage, hold the vehicle in place, attach pulls, and relieve all the stress in the unibody. Damaged bolt-on parts may block access to underlying damaged structural components. Damaged bumper covers, bumper reinforcements, header panels, fenders, hoods, doors, deck lids, or rocker panel moldings must be removed before starting work on the vehicle. Damage to the center section of the vehicle may require removal of portions of the interior, such as the seats, carpet, interior trim panels, shoulder belts, and headliner.

While removing bolt-on parts, always keep the fasteners for each part in a separate labeled bag or container. This will allow easy identification of fasteners during reassembly. Keep damaged parts until the repairs are complete. The damaged parts may have clips, moldings, or fasteners that are needed to assemble the vehicle.

Some movable parts may be so badly damaged that the damage prevents the part from opening. For example, on a front hit vehicle, the hood and radiator support may be pushed back so the hood latch will not release. Try inserting a crowbar between the radiator support and the hood to pry the hood open. Damage may also block access to fasteners. A front hit may fold a fender so the damaged portion of the panel covers the fender bolts. In this example, use a cut-off tool to cut the damage out of the way for access to the fasteners.

Identify Damage

Unibody damage can range from obvious to subtle. ***Obvious damage***, such as torn metal, buckles, and kinks, is fairly easy to identify, **Figure 15-1**. ***Subtle damage***, such as slight bulges and bends, can be missed during a casual damage inspection. See **Figure 15-2**. To find subtle damage, inspect the vehicle from underneath first. Work your way out from the point of impact. Look for raised areas between spot welds,

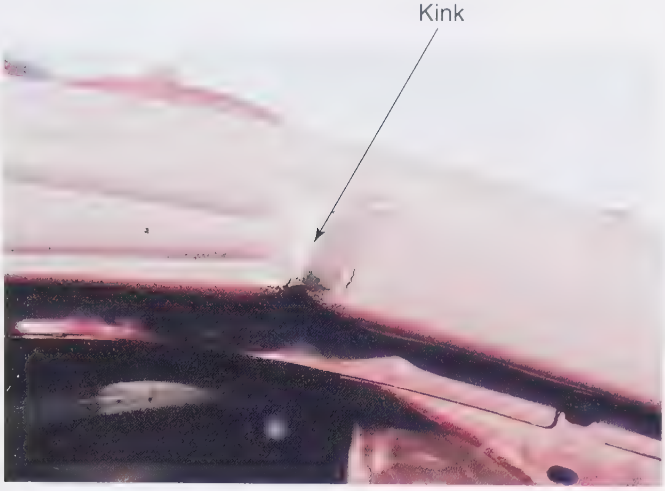


Figure 15-1. *This unibody vehicle was hit in the front. The collision force traveled through the body and caused a kink in the upper frame rail.*

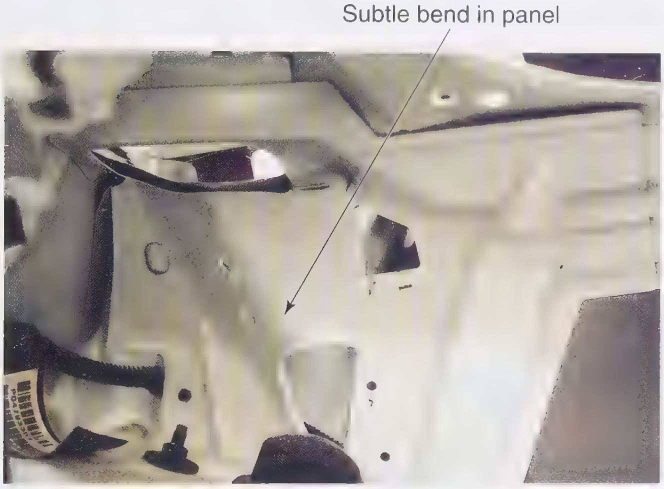


Figure 15-2. *This unibody vehicle was hit hard in the left rear. The collision force caused a bend in this support panel. The panel damage is subtle.*

out-of-level dimples in convolutions, and cracked or split caulking. Then check the upper part of the vehicle for these problems, as well as for slight panel misalignment. All subtle damage must be removed when straightening the unibody.

All damage causes stress in the steel panels. The stress is a rearrangement of the regular pattern in the grains of the steel. A kink is a drastic rearrangement of the grains in high-strength steel. The grains in a kink are so distorted that even if the panel is pulled and length restored, the panel will be weak. Kinked high-strength steel panels must be replaced. A bend causes a less drastic rearrangement of the grain pattern in high-strength steel than a kink. The strength of a bent panel is not affected. Proper repair methods will restore the length and grain arrangement in bent high-strength steel panels. Because it is impossible to look at a structural panel and determine if it is made from high-strength steel, treat all structural panels as if they are made of high-strength steel.

At minimum, two-dimensional centerline gauges, supplemented with linear measurements, should be installed on the vehicle to locate damage. The sequence of centerline gauge checks on a unibody vehicle is twist, level, centerline, datum, and then linear measurements. Draw a damage diagram to indicate misalignment.

If three-dimensional measuring equipment is available, follow the measuring system instructions to identify damage. Computer-aided measuring systems will usually generate and allow you to print out a diagram of the vehicle, indicating the amount and location of damage. If the three-dimensional measuring system does not print out a damage diagram, draw out a diagram of the vehicle and label the damage.

Plan

You should always establish a repair plan before straightening a unibody vehicle. You must determine how to tie down the vehicle, where to make hookups, and how to straighten the damage. Review the damage diagram or printout made during the identification of the damage. Use the damage diagram as a map to plan how the structural components must be moved or held stationary to correct the damage. On the diagram, draw the direction in which the pulls will be made.

When planning the repair of a unibody vehicle, think of the vehicle as being divided into three sections: front, center, and rear. Damage to the center section can have an effect on one or both of the end sections. For example, twist—a condition in which the corners of the center section are not level when viewed from the front—will cause an out-of-level condition in the front and rear sections. The damage in the center section will cause misalignment in the end sections. Attempting to straighten the end sections first will cause additional damage. Repairing the twist in the center section may cause the end sections to align. Once the center section is aligned, any remaining damage in the end sections can be repaired.

Damage should be corrected in the order opposite to that in which it occurred. The repair sequence for a unibody should begin by correcting twist and then mash. Once the length is restored, the width or height can be corrected next. Determine which is more out of specification, and correct that next. If the centerline (width) is off by 30 mm and the height is off by 10 mm, correct the sidesway first and then correct the height.

Figure 15-3 shows an example. The damage diagram shows sidesway and sag on the lower unirails. The plan shows a side pull to correct the sidesway. Forward pulls on each unirail will remove the last bit of sidesway, followed by pushes on the unirails to restore height.

As stated previously, the center section of the vehicle is restored to proper dimensions first. Then, the end sections are repaired by correcting the length first and then the height or width. Lengthening the damage corrects mash, restoring height corrects sag or kickup, and setting the width to specifications corrects sidesway.

Tie-Downs

Tie-downs are used to hold a vehicle in place during pulling and pushing. The tie-downs must be stronger than the pull. Most unibody vehicles are tied down by ***pinch weld clamps*** placed on the bottom of the rocker panels. **Figure 15-4** shows a typical pinch weld clamp in position. The clamp is bolted to the vehicle pinch welds and to the bed of the frame machine. Four clamps are installed, one at each corner of the center section. When properly tied down, the center section cannot move forward, rearward, sideways, or up and down.

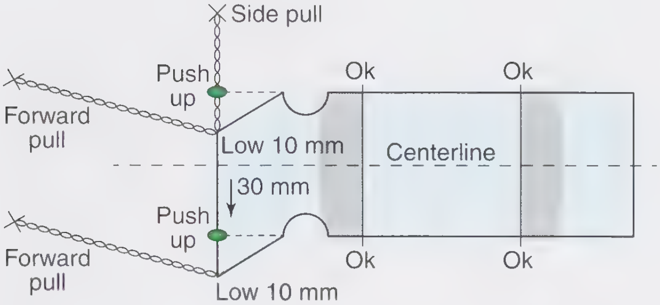


Figure 15-3. *A damage diagram is used to analyze the damage and plan the pulls.*

Normally, all four pinch weld clamps are installed on the center section of the vehicle. However, in the case where a front impact on the lower frame rail has made one front corner of the center section higher than the other, the clamp can be left off the high corner while the other three clamps are installed. Straight ahead pulling causes the unibody to move down, so pulling the lower frame rail straight ahead will cause the high corner of the center section to move down. This may be enough downward movement to correct the damage. Similarly, only three pinch weld clamps should be installed if a rear corner of the center section is low and a downward pull will be made at the front of the vehicle. Do not install the clamp on the low corner. A downward pull at the front of the vehicle will tend to raise the rear of the vehicle. The unclamped corner will move up while the front is pulled down. The upward movement at the rear may be enough to correct the damage.

Additional tie-downs can be used to immobilize other areas. Consider, for example, a vehicle that is hit on the right front side, moving the right upper frame rail in and bending the radiator support, but not damaging the left upper frame rail. A side pull on the right upper frame rail may move the left upper rail also. To prevent this problem, a tie-down is made on the left rail. The tie-down should be at the same height and angle as the pull. See **Figure 15-5**.

Blocking can be used to maintain the height of an area during a pull, as well as to change the height of an area or act as a pivot point during a down pull. Blocking is the equipment used to prevent downward movement of structural parts during structural repairs.

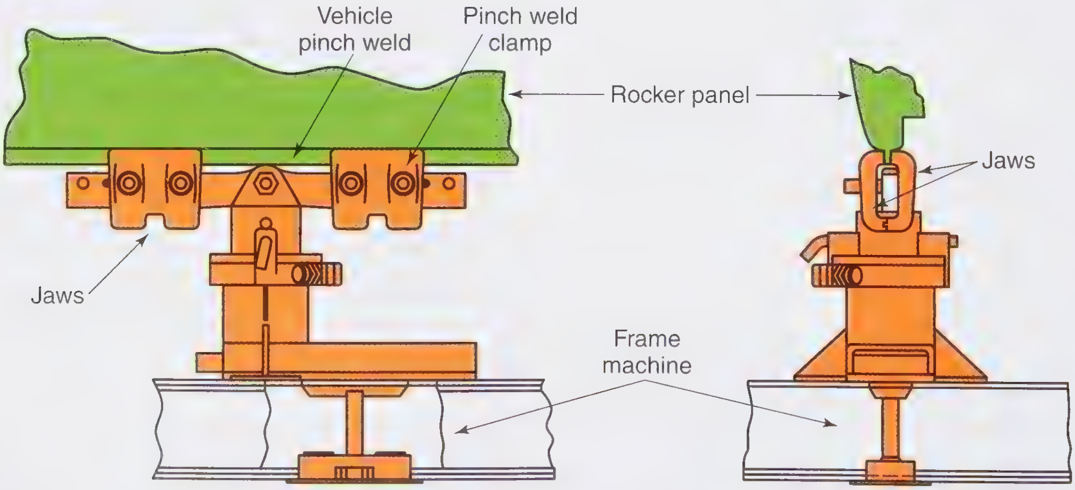


Figure 15-4. *The jaws of the pinch weld clamp are bolted together to grasp the pinch weld.*

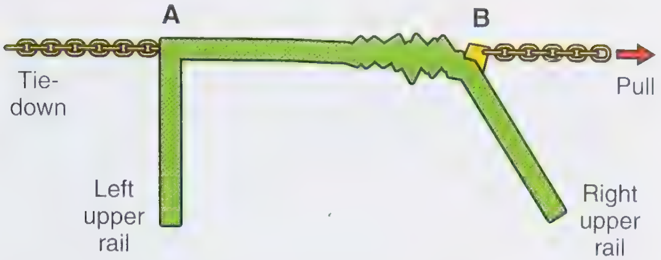


Figure 15-5. *The tie-down immobilizes the undamaged left upper rail. The pull straightens the damaged radiator support and right upper rail.*

See **Figure 15-6**. The pinch weld clamps bolted to the unibody and tied to the frame machine or floor are considered blocking because they prevent downward movement, as well as upward movement, during a pull. Other types of blocking are 10-ton hydraulic rams and extensions, jack stands, and stacks of hardwood blocks. For example, if one lower frame rail is high and needs to be pulled down but the lower frame rail on the other side of the vehicle has no damage and therefore is at the proper height, blocking is placed under the undamaged frame rail so it does not move down as the damaged rail is pulled down. The blocking concentrates the pulling force on the damage. See **Figure 15-6A**. If one frame rail is high and the other is low, blocking can help raise the low rail while the high rail is pulled down. See **Figure 15-6B**. In this example, the low rail is blocked to be slightly higher than normal.

As the high rail is pulled down, bending takes place at the blocking. The blocking raises the low side as the pull lowers the high side. The rail is blocked slightly higher than normal to account for the settle back that takes place during pulling.

Blocking can also act as a pivot point during a down pull. If a unibody frame rail is bent up, the blocking can be placed in the undamaged area adjacent to the buckle. As the frame rail is pulled down, the blocking concentrates the pull force on the buckle. See **Figure 15-6C**. Well thought out blocking can make structural repairs much easier.

Hookups

Hookups are used to attach the pull to the vehicle. Unibody sheet metal can tear if too much force is applied to a small area. **Figure 15-7** shows a clamp that has taken a bite out of a unibody. To prevent this problem, make multiple hookups. Multiple hookups spread the force of the pull over a wider area. With pull force spread out, the metal is less likely to tear. If a choice is available between two clamps that will do the job,

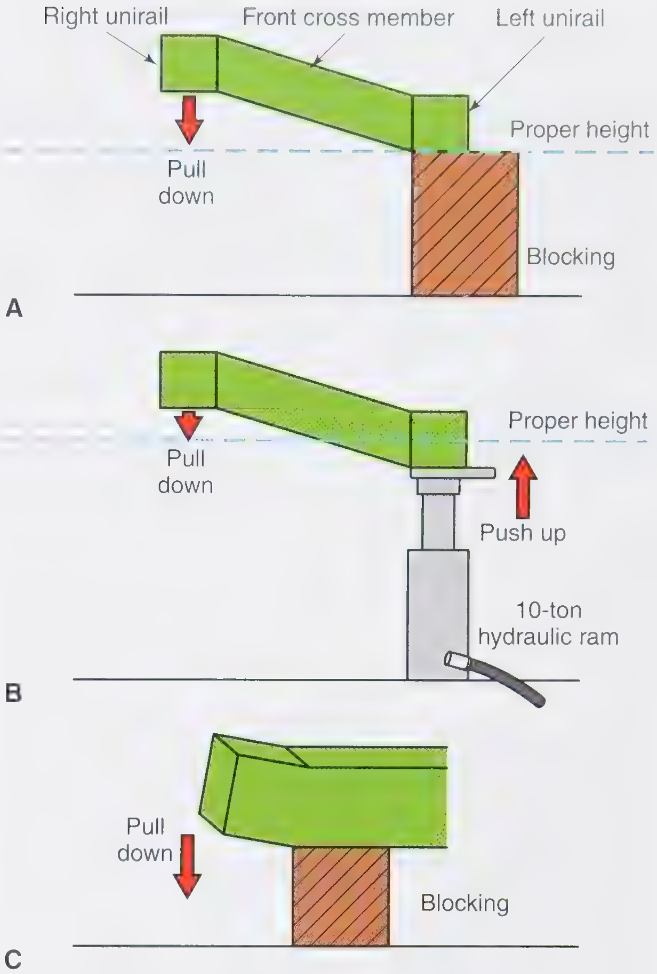


Figure 15-6. *A—The undamaged left lower unirail is blocked with a wood block at the correct height. The damaged right lower unirail is pulled down to the correct height. B—A 10-ton hydraulic ram is used to help raise the left unirail while the right lower unirail is pulled down. C—Blocking placed just to the rear of a buckle acts as a pivot point when the front of the unirail is pulled down.*

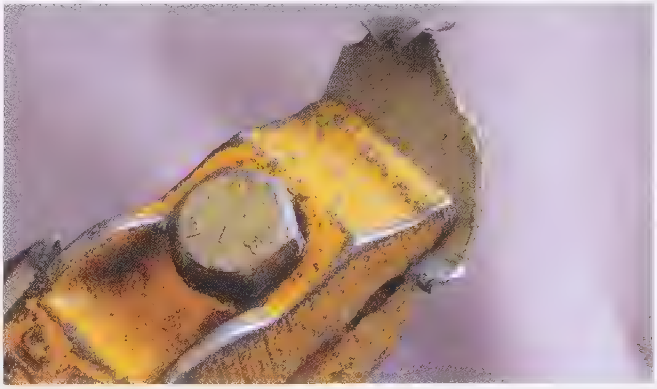


Figure 15-7. *Unibody sheet metal can tear if too much force is applied to a small area.*

choose the clamp that has wider jaws to grab more surface area. See **Figure 15-8**. This will spread the pull force in a wider area; a narrow jaw clamp may concentrate the pull force in a small area and tear the metal.

Figure 15-9 shows various types of hookups. **Figure 15-9A** shows two clamps pulled by different chains. On a forward pull, the clamps are usually pulled at the same rate. On a side pull, the impact side should lead when pulling. **Figure 15-9B** shows a hook being used to pull out damage. The hook can reach around obstructions. Only the friction of the hook and the pull angle hold these hooks in place.

Figure 15-9C shows a bolt-on plate in use. The bolt-on plate concentrates the pull force on the bolt, nut, and the area the plate is bolted to. The area the plate is bolted to must be strong enough to transfer the pull force to the damaged area without tearing. **Figure 15-9D** shows a strut tower pull. The hookup fits around the strut tower and is used to pull the tower into place.

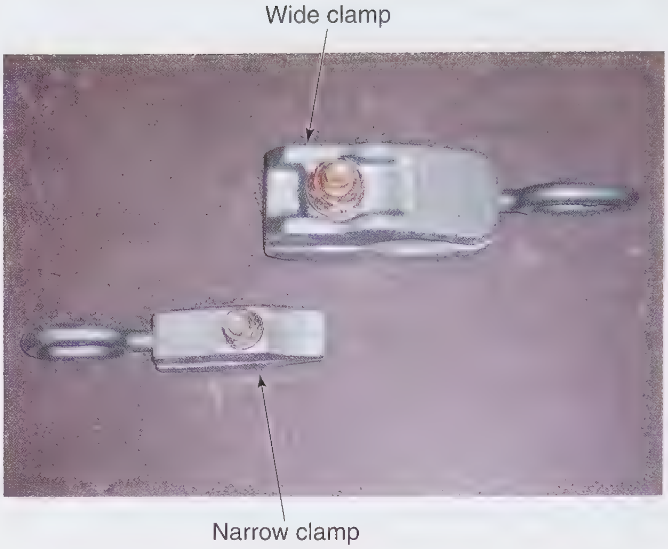


Figure 15-8. *The wider clamp is less likely to tear sheet metal than the narrow clamp.*

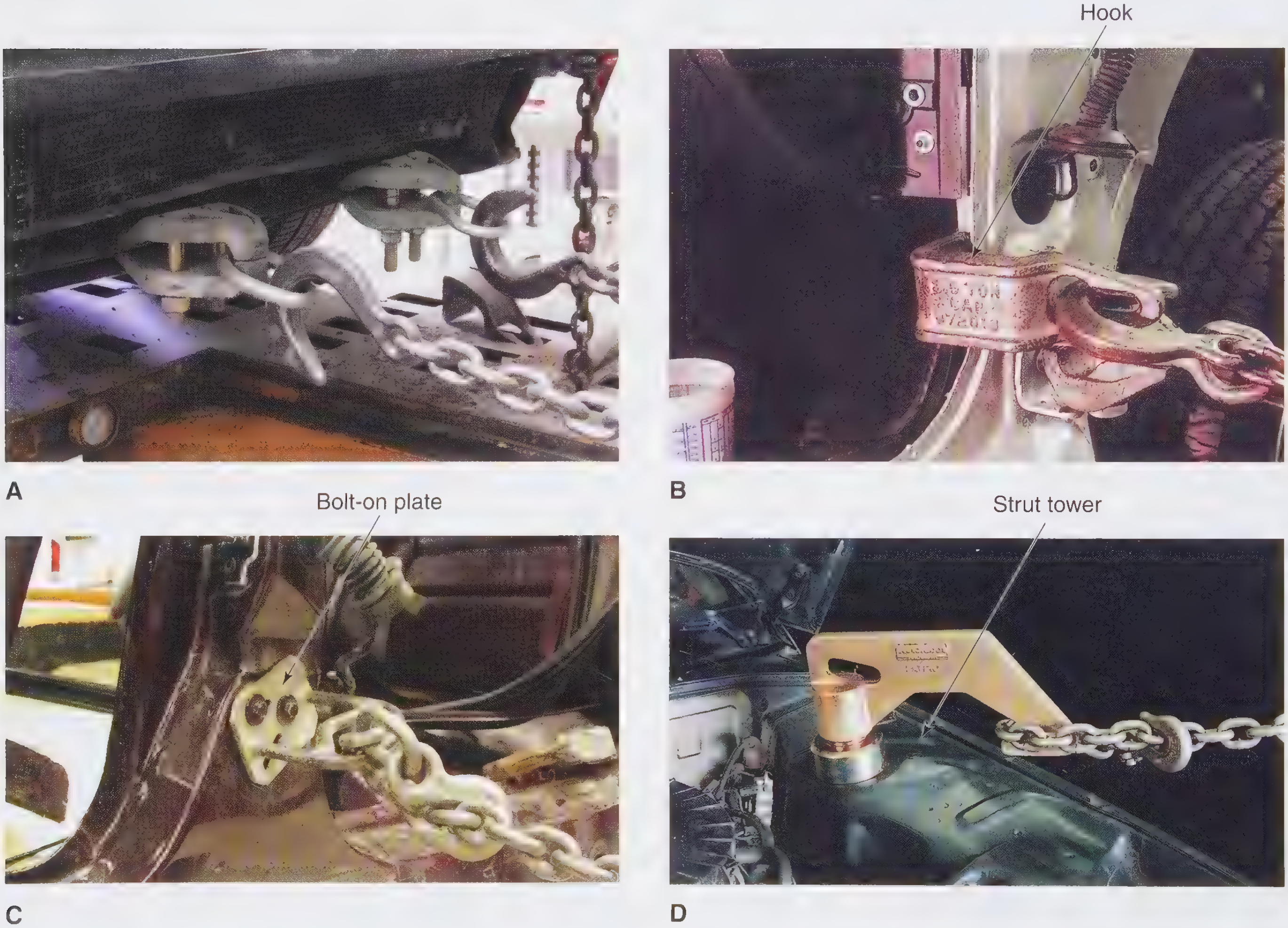


Figure 15-9. *A—Two clamps pulling on one panel spreads the force of the pull to minimize tearing. B—A hook makes a quick, but not very secure, hookup. C—A bolt-on plate makes a quick hookup to a center pillar. D—This hookup is designed to move the strut tower. Notice that the pull chain alignment is in line with the area where the tool is attached to the top of the strut tower. (Autorobot)*

Straightening Damage

Sheet metal straightening is a very important aspect of unibody repair. As explained in Chapter 4, Fundamentals of Collision Damage, severe buckles cannot be simply hammered out. Hammering on a severe buckle without lengthening the panel by pulling will cause additional damage. The grains in a buckle are locked in place. Hammering on the locked grains will cause more buckling. Controlled movement of the damaged metal and restoration of the grain pattern will unlock the buckle.

Heat can be used to restore the grain pattern. Heat causes the grains to vibrate rapidly. However, uncontrolled heat will cause high-strength steel grains to increase in size, weakening the steel. In mild steel, heat will not cause weakening.

Spring hammering is another way to restore the grain pattern in damaged metal. Structural components are placed under tension during a pull. While the component is under tension, spring hammering on the component will cause the grains to vibrate and move toward their original, undamaged arrangement. A body hammer can be used or blocks of wood can be placed on the component and the block of wood hit with a ball peen hammer. Several spring hammer blows are required to return the grains to the proper arrangement.

The correct way to remove buckles is to apply pulling tension. The tension force starts to move the buckle in the proper direction. Light tapping with a body hammer or spoon around the buckle vibrates the metal, releasing the stresses in the surrounding metal and allowing the buckle to unlock. Only when the buckle has unlocked can it be hammered on directly.

Many times buckles are found on box members, channels, or pillars. **Figure 15-10** shows an example of a buckled pillar. The shape does not allow access to the back side of these panels. To repair these bent parts, the part is pulled or pushed into its proper location and all stress is relieved by spring hammering. If dents remain, they must be straightened with a draw pin welder and one-sided body repair techniques.

Tolerances must be considered when repairing structural damage. In unibody repair, the tolerance for many vehicles is plus or minus 1/8" (3 mm). This means that if a linear measurement of a repaired structural component is within 1/8" (3 mm) of specification, the component is close enough to the specification to be acceptable. A measurement that is outside the tolerance is not acceptable. Additional corrections must be made to bring the part into the acceptable range. On some vehicles, only the specified measurement is acceptable.

Tolerances also apply to comparison measurements, such as x-checks. Comparison measurements should be within 1/4" (6 mm) of each other. For example, if one leg of an underhood x-check is 997 mm and the other leg is 1001 mm, the difference is 4 mm. These dimensions are within 1/4" (6 mm) of each other, the tolerance for an x-check. Although the hood opening is not perfectly square, it is within the acceptable range. If a measurement is out of tolerance, the body parts may not fit properly.

Pulls

Pulls are used to return damaged parts to their original positions. A pull will always attempt to exert a force in a straight line between the origin of the pull and the tie-down. **Figure 15-11** shows a diagram of a unibody vehicle that has been hit in the front. The radiator support is pushed rearward. The bending of the radiator support pulled the upper frame rails toward the center of the vehicle. A forward pull at *B*, by itself, would not correct the damage; the upper frame rails would still

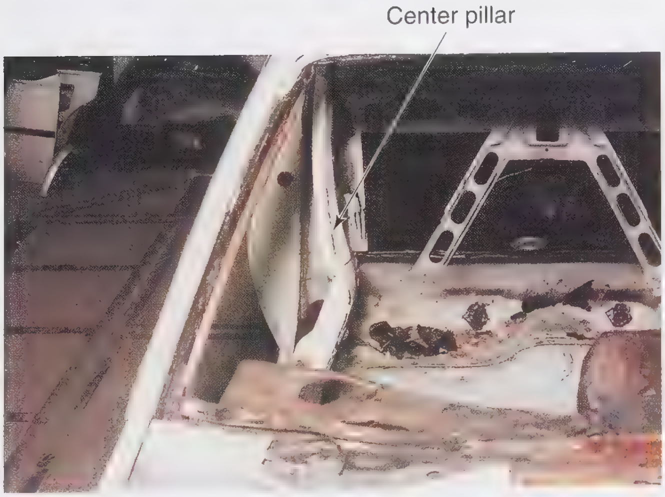


Figure 15-10. *This center pillar has a severe buckle.*

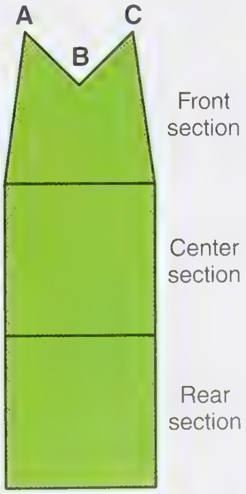


Figure 15-11. *Damage at B has caused A and C to move toward the center.*

be bent in toward the center of the vehicle. The correct method to repair this damage is shown in **Figure 15-12**.

WARNING

Never stand directly behind or straddle chains while the vehicle is under tension.

In this repair, the upper frame rails are both pulled away from the vehicle's centerline. As *A* and *C* are moved outward, the radiator support's width increases, pulling out most of the damage. A straight-ahead pull is then made at *B* to remove the buckle at *B*. During the collision, *B* moved in first, then *A* and *C*. During the repair, this order is reversed. The component that moved last is corrected first. This example shows the value of making multiple pulls in different directions. Multiple pulls are commonly used when making unibody repairs.

Types of Pulls

There are several types of pulls used to repair unibody damage. The type of pull used depends on the type of damage being repaired. See **Figure 15-13**. The common pulls include:

- ***Forward pull***—Used to increase length of a damaged part parallel to the vehicle's centerline. A forward pull corrects mash and sidesway.
- ***Double stretch pull***—Two pulls in opposite directions will straighten and then lengthen whatever is in between. A double stretch pull can correct mash and sidesway.

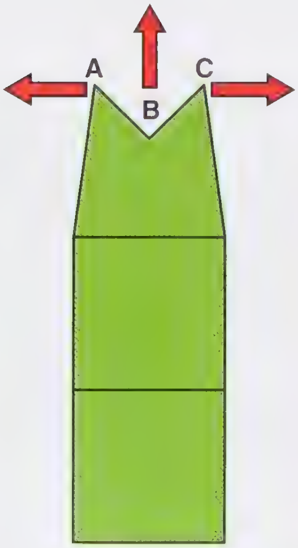


Figure 15-12. *Pulls at A and C allow the radiator support to increase in width. A pull at B corrects the remaining damage.*

- ***Side pull***—Used to increase width at a 90° angle from centerline. This type of pull corrects sidesway.
- ***Angle pull***—A pull made in between 90° from centerline and parallel to centerline. An angle pull can correct mash and sidesway.
- ***Downward pull***—Used to lower an area. This type of pull is used to correct kickup and twist.
- ***Upward pull***—Used to raise a damaged area. An upward pull corrects sag.
- ***Combination pull***—A combination of angle and downward pulls or angle and upward pulls. A combination pull can be used to correct mash, sidesway, twist, sag, and kickup.

Pull direction is very important in unibody repair. There is a saying in structural repair, "Pull the damage out in the direction opposite the way it went in." In many cases, this is true. **Figure 15-14** shows an example of this idea. Both A and B must be moved forward and to the right. Making a 45° pull or a combination of forward and side pulls approximates the angle at which this vehicle was hit. The angle may need to be changed if A straightens faster than B. The pulling direction can be modified during the pull as needed. Another way to pull at a 45° angle is shown in **Figure 15-15**. In this case, there are two separate pulls, a forward pull and a side pull. The forward pull restores the length and the side pull corrects sidesway. These pulls should be made gradually, not all at once. Pull forward slightly and leave the tension on. Then pull to the side slightly, leaving the tension on. Continue to alternate between forward pulls and side pulls, gradually working the damage out. Pulling in one direction at a time is preferred to making two pulls in different directions at the same time because two pulls in different directions at the same time tend to get in each other's way.

The term ***multiple pull*** means to make more than one pull at one time. Two or more simultaneous pulls in the same direction spreads the corrective force. Always use multiple pulls in the same direction, if possible. Each pull contributes to the corrective force. Each pull may be relatively weak, but when several weak pulls are combined, considerable force can be applied. Less individual force is required to accomplish a task when multiple pulls are made. If a pressure gauge is available on the frame repair equipment, try to keep the ram pressure below 3000 psi. With multiple pulls, this can be easily achieved.

During a collision, the unibody panels, which are spot-welded together, may be ripped apart. The collision force breaks the spot welds as the panels separate. As the panels are pulled during repair, the panels, including the torn spot welds, will line up. These torn spot welds can be welded to join the panels. Pulling on two panels rather than one is less likely to tear the sheet metal of the unibody.

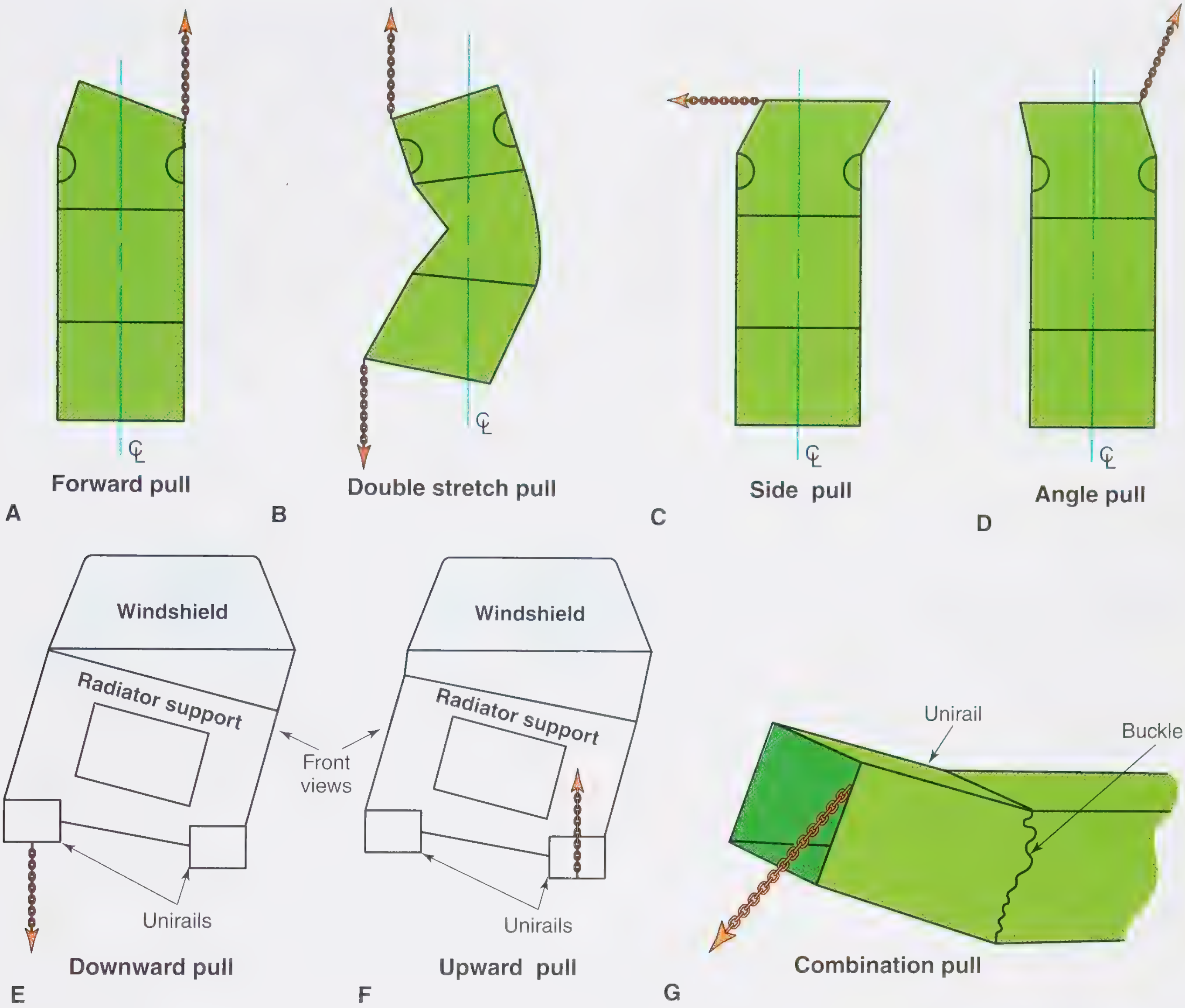
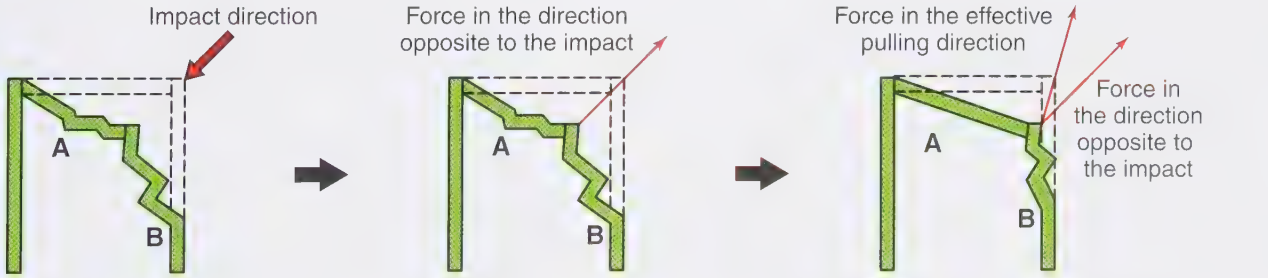

Forward pull
A
Double stretch pull
B
Side pull
C
Angle pull
D
Windshield
Radiator support
Front views
Unirails
Downward pull
E
Windshield
Radiator support
Unirails
Upward pull
F
Unirail
Buckle
Combination pull
G

Figure 15-13. *The common pulls used to repair unibody damage are shown. A—A forward pull is parallel to centerline. B—A double stretch pull is parallel to centerline. C—A side pull is perpendicular to centerline. D—An angle pull cuts across parallel and perpendicular. E—A downward pull lowers a high area. F—An upward pull raises a low area. G—A combination pull is a hybrid of many pull directions.*


Impact direction
A
B
Force in the direction opposite to the impact
A
B
Force in the effective pulling direction
Force in the direction opposite to the impact
A
B

Impact force was in the direction of the red arrow, causing deformation shown.

Apply force in the direction opposite to the impact force.

If a difference in the degree of repair between A and B occurs, change the pulling direction accordingly.

Figure 15-14. *In this collision, damage occurred at both points A and B. An angle pull in the direction of the impact force will correct the damage if A and B move equally. If A and B do not move at the same rate, the angle can be changed to compensate for the differences.*

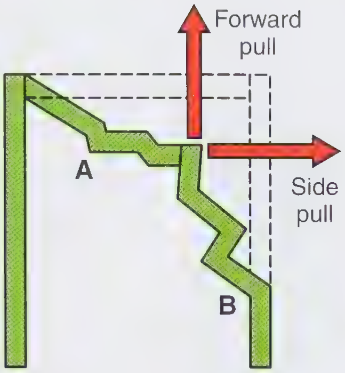


Figure 15-15. *In this example, pull slightly forward at A first; then slightly to the side at B. Continue to alternate pulls between A and B, gradually working out the damage.*

WORKING SMART

Pulling on a cracked or torn unirail will tear it apart. Prevent tearing by making a MIG weld on the crack or tear before pulling. The weld will tie the two sides of the metal together, allowing the pull to act on both sides of the damage. It may be impossible to fit the MIG nozzle into a severely folded unirail. When this is the case, pull the rail and make the weld as soon as possible. If only part of the crack can be welded, weld the portion that is accessible and weld the rest as the unirail unfolds.

When making a pull, watch for movement in the vehicle. All movement should take place in the damaged area. Movement outside the damaged area can cause major problems. The tie-downs should not move. If the damaged area is not moving when the pulling force is applied and the pressure gauge on the ram indicates 3000 psi. or more, stop the pull. Under that amount of pressure, the damage should move if the hookups and pull directions are correct. Continuing to pull without any movement will cause something to break, usually the unibody. Stop the incorrect pull and rethink the procedure.

Overpulling means that the damaged panel is moved slightly beyond the correct location to account for settle back. ***Settle back***, also known as spring back, means that once the tension is released, the panel returns to a position that indicates damage. Settle back can be minimized with proper stress relieving techniques. Pulling beyond the correct location allows the panel to settle back in the proper location once tension is removed. Overpulling can be easily misused. Excessive overpulling will cause major problems that are difficult to repair. As with all structural pulling and pushing, overpulling must be done gradually as there are no established guidelines for the amount of overpull required to correct for settle back. The procedure is to pull until the proper dimensions are achieved, release tension, and measure. If settle back has occurred, overpull slightly, (about 1/8" or 3 mm) and measure again. If the overpull does not correct the settle back, increase the overpull by 1/8" and measure. Repeat this sequence by adding 1/8" each time until the proper dimension is achieved.

Pushes

In some cases, pushes are used to repair unibody damage. Some frame equipment is designed to make pushes, but in this chapter we will discuss pushes made with a hydraulic ram.

The hydraulic ram pushes in two directions at the same time. It pushes as hard against its base as it does against the object it is intended to move. If the base is the shop floor or the bed of a frame machine, this is not a problem. However, if the base is a portion of the vehicle, the area where the ram is based must be stronger than the damage itself. If not, the base will be damaged. Spread the force of the base out by placing the ram on blocks of wood as shown in **Figure 15-16**. Another way to spread the force is to use a piece of angle iron and the ram attachment shown in **Figure 15-17**. Another concern is that a push may crush whatever it is intended to move. This is especially true of box members. A box member is weak in the center but stronger on the corners. Therefore, the push should be made at a corner whenever possible. Always position the ram at the base and use extension tubes to reach the damage.

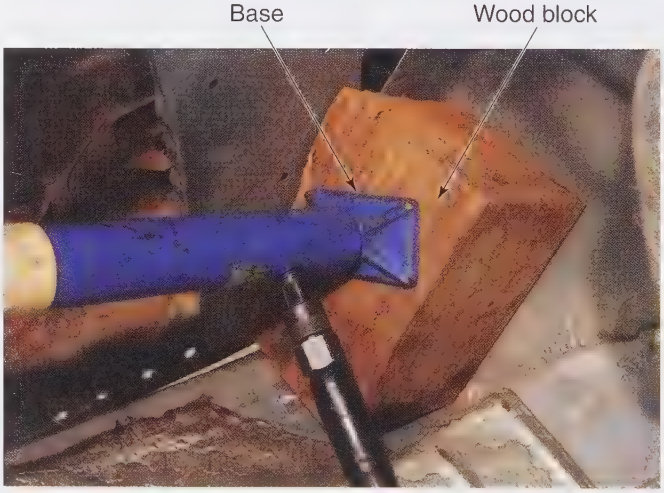


Figure 15-16. *The base of the hydraulic ram can damage sheet metal. Spread the force of the push with a block of wood.*

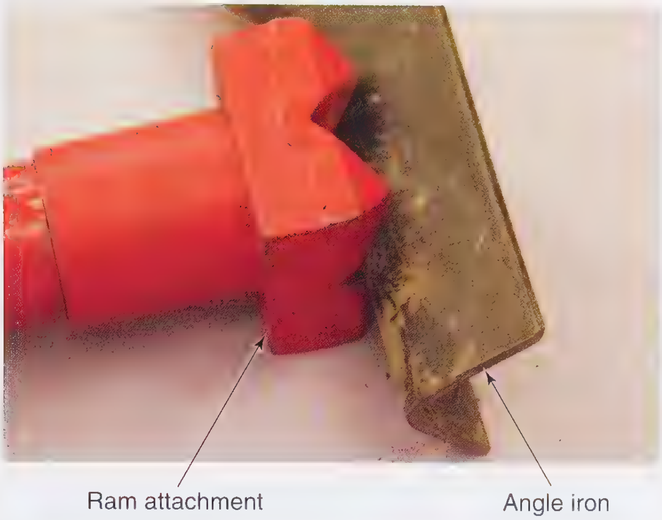


Figure 15-17. *The angle iron on the ram attachment will spread the force on a box member, minimizing the chance of damage to the box member.*

Stress Relief

Stress results when a unibody vehicle absorbs collision energy. This stress is actually a rearrangement of the steel grain structure. To properly repair a unibody vehicle, all the steel grain must be returned to the original undamaged state. This process is called ***stress relief***. Stress is relieved when the vehicle is under pulling tension. The tension gives the metal a direction to move. Stress relief provides energy so that the grains will move in the direction of the pull. **Figure 15-18** shows the grain arrangement of undamaged and damaged steel.

There are two methods that can be used to relieve stress: spring hammering and heat. Both spring hammering and heat supply energy to the metal grains. In spring hammering, the energy is from vibration. Heat causes the metal molecules to move about with greater speed. Both methods change the grain arrangement.

Spring hammering is shown in **Figure 15-19**. A body hammer can be used, as well as a spoon or a block of wood. The idea is to spread the force of the blow over a large area. An example of a damaged vehicle is shown in **Figure 15-20**. The areas to be spring hammered are indicated. Start by placing the damage under a pull. Avoid standing in front of chains under tension. To prevent snap back, make sure the chains are secure.

Begin spring hammering at the farthest point of the stress. Rapid, light blows are best. Tap the spot welds and the metal between the spot welds; corners of box members, channels, and pillars; and convolutions. Gradually work toward the direct damage. When spring hammering is done properly, the damaged panel will lengthen in the direction of the pull. This is similar to the crumpled piece of paper that was straightened by flattening the folds.

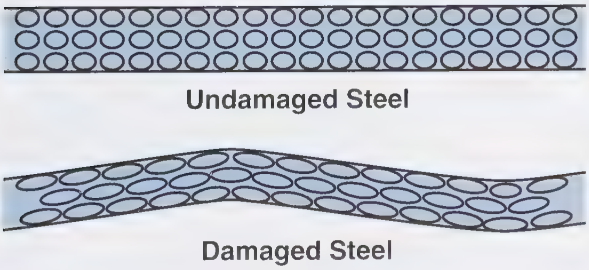


Figure 15-18. *Collision force rearranges the grain structure in steel.*

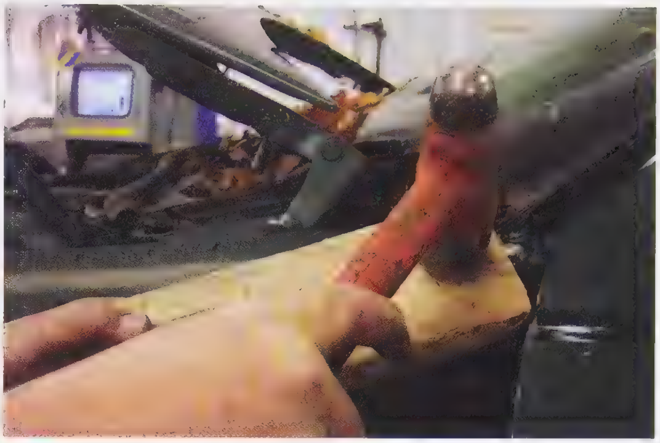


Figure 15-19. *A block of wood spreads the force of the spring hammering. This vehicle is under tension from a downward frame pull.*

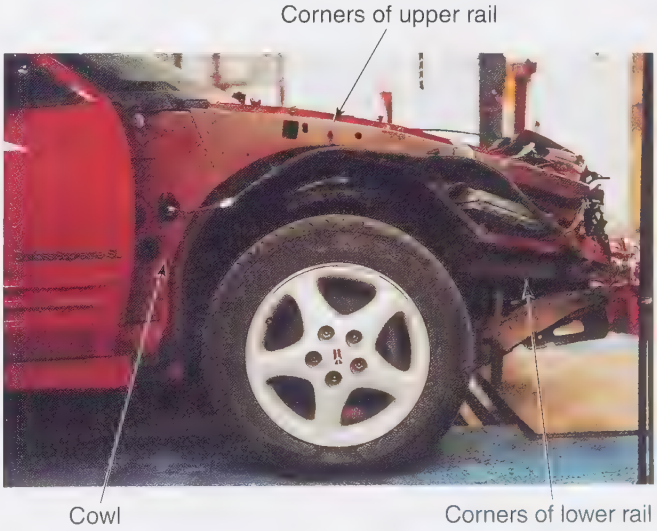


Figure 15-20. *The corners of the rails and the cowl should be spring hammered to relieve stress.*

The pull chain tension will slacken as the panel lengthens. This can also be seen as a drop in pressure on the pressure dial. If more movement is needed, apply additional tension and continue to spring hammer. Work around buckles. Do not hammer directly on them until they have flattened under tension.

Heating causes the molecules in the metal to move rapidly, relieving stress and softening buckles in damaged steel. Heated buckles are much easier to repair. High-strength steel will be damaged by excessive heat. Too much heat will destroy the grain structure of high-strength steel. High heat causes the grains in high-strength steel to grow in size, eliminating the tight, orderly grain structure that provides strength. During repair, bent high-strength steel should be heated according to the vehicle manufacturer's guidelines. See **Figure 15-21** for heating recommendations.

Recommendations for Heating High-Strength Steel

Manufacturer	Recommendation
Acura	Do not apply heat.
Audi	Do not apply heat.
BMW	Do not apply heat.
Chrysler	Do not heat over 1050°F (560°C).
Ford	Do not heat over 1200°F (650°C).
General Motors	Do not heat over 1000°F (540°C). Do not apply heat for more than 90 seconds. Do not apply more than 2 applications of heat.
Honda	Do not apply heat.
Infiniti	Do not heat over 1020°F (550°C). Avoid use whenever possible.
Lexus	Do not apply heat.
Mazda	Do not apply heat.
Mercedes-Benz	Do not apply heat.
Nissan	Do not heat over 1020°F (550°C).
Porsche	Do not apply heat.
Saab	Do not heat over 1200°F (650°C).
Suzuki	Do not apply heat.
Toyota	Do not apply heat.
Volkswagen	Do not apply heat.
Volvo	Do not apply heat.

Figure 15-21. *This table lists vehicle manufacturer heating recommendations for high-strength steel.*

CAUTION

Be sure to reference the manufacturer's recommendations for the vehicle being repaired. Many vehicle manufacturers do not allow damage to be heated.

Use an oxyacetylene torch with a tip having an orifice the same size as would be used to weld the thickness of metal. Adjust the torch to a neutral flame. Before applying the flame, remove the paint from the area to be heated. Also remove any components that may be damaged by the heat or flame, such as brake lines, gas lines, or hoses. Keep the flame at least 6" away from any foam that may be inside the unirail. The foam can catch on fire and release toxic gas.

The area to be heated should be about six to seven times the width of the buckle. See **Figure 15-22**. On unibody frame rails, heat only the corners of the rail or the buckle, not the center of the rail. Gradually raise the temperature of the panel by holding the torch about one foot from the panel and moving the torch back and forth. Slowly decrease the distance with each pass. Stop moving in once the tip of the flame touches the panel.

One way to determine the temperature of a heated panel is to use a ***heat crayon***, shown in **Figure 15-23**. The heat crayon will melt at the specified temperature. For example, if the manufacturer's recommendations state that the damaged high-strength steel panel cannot be heated above 1200° F (648° C) for 1 1/2 minutes, use a 1000° F (537° C) crayon. By using a crayon that is below the maximum temperature, the technician is less likely to overheat the panel. Heat crayons are difficult to use. One method of use is to apply the crayon to the panel, heat the panel, and watch for the crayon to melt. A heat crayon that melts at 1000° F cannot be applied to a panel unless the panel is heated to at least 500° F (260° C). Once the crayon is smeared on the heated panel and the panel

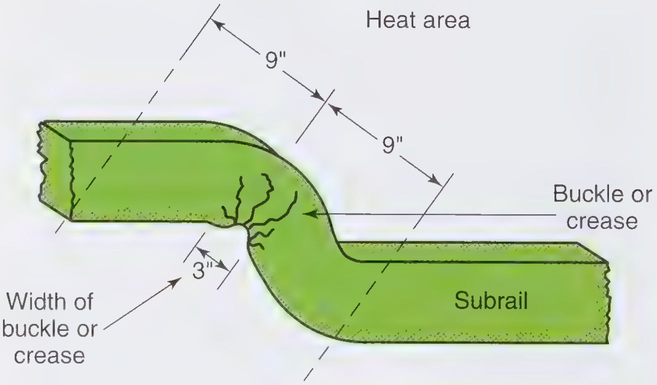


Figure 15-22. *Heat the corners of the rail and the buckle in an area six to seven times the width of the buckle. (Chief Automotive Systems)*

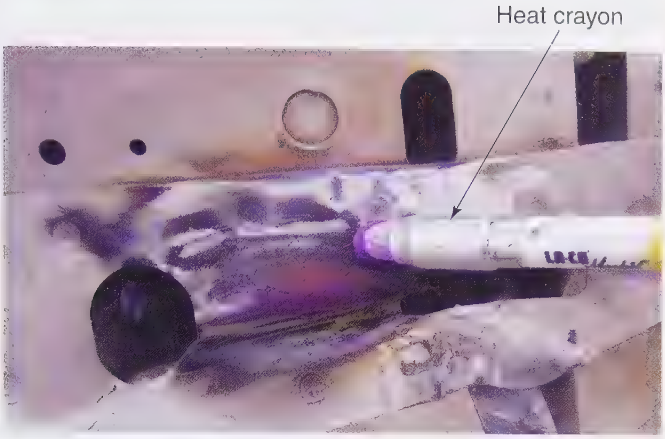


Figure 15-23. *Heat crayons will not smear on the metal until the metal is heated to at least half the temperature listed on the crayon. For example, the metal must be heated to at least 500° F to apply this 1000° F heat crayon to the metal.*

is heated to 1000° F, the crayon mark melts and disappears without any warning. Also, in this method, the crayon must be applied to the area adjacent to the buckle, so the temperature of the buckle can only be approximately determined. The crayon cannot be applied directly on the buckle, because the crayon cannot be seen in the bright light of the torch.

The other way to use the 1000° F heat crayon is to heat the panel, remove the torch, and then smear the crayon on the heated area. If the crayon melts on contact with the heated metal, the panel has been heated to at least 1000° F.

An ***infrared thermometer*** can also be used to determine the temperature of a heated panel. The thermometer should be able to detect a temperature of at least 1000° F. To use this thermometer, heat the panel, remove the flame, and then measure the temperature with the thermometer. See **Figure 15-24**. Aim the thermometer at the hottest part of the heated area, in this case at the glowing red buckle. If carefully done, this method will work. The panel must be heated slowly and the temperature must be checked often. It is easy to be in a hurry and overheat the damage.

Kinked panels, which will be replaced, can be heated during repair. Do not heat any areas that will not be replaced and stay at least 2" away from any part that will be used to splice to.

Straightening Specific Types of Unibody Damage

The following procedures involve using the skills or operations discussed previously to correct specific types of unibody damage. Each procedure includes tie-down, hookup, pull, and stress relief techniques.

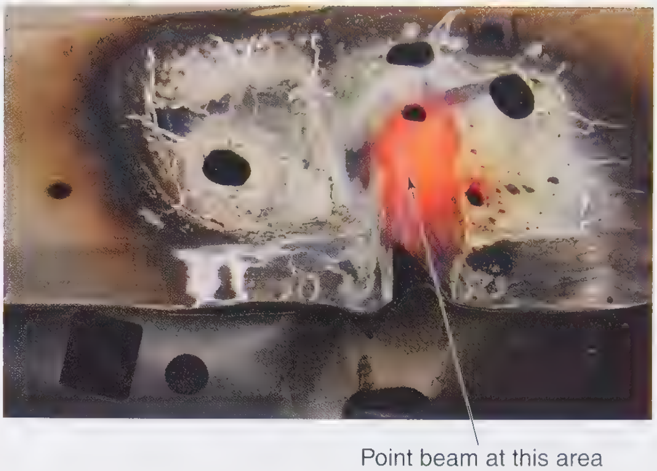


Figure 15-24. *An infrared thermometer can be used to determine the temperature of a heated frame rail. Point the beam from the thermometer at the hot spot.*

Unirail Flange Bent

A bent unirail bumper mounting flange is shown in **Figure 15-25**. This type of damage is common on front impacts. There is no other damage on the unibody. To straighten out this damage, use a frame block as shown in **Figure 15-26**. This type of repair does not require tie-downs or pulls. Simple sheet metal repair by tapping around the buckles and straightening the flange will accomplish the task.

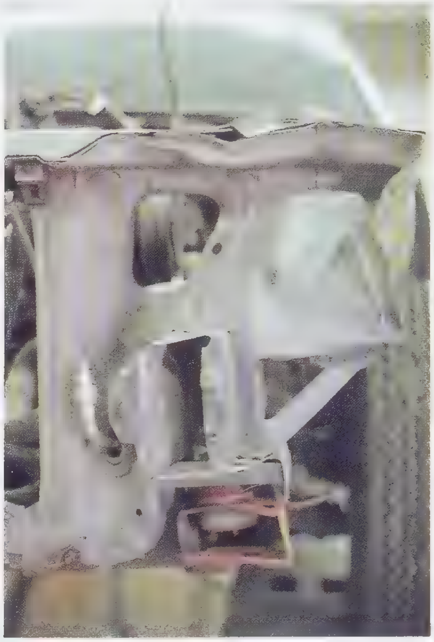


Figure 15-25. *An impact on a bumper can damage the bumper mounting flange.*

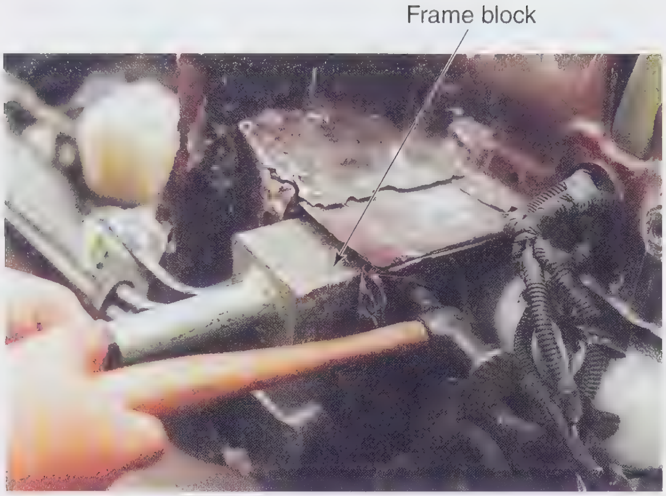


Figure 15-26. *A dolly and hammer are used to straighten a bumper mounting flange.*

Front Unirail Sag

If a unirail is bent downward, identify the kinked or bent area and place a tie-down to the rear of the damage. A tie-down on the undamaged frame rail will prevent the undamaged frame rail from moving up, concentrating the push on the damaged rail. The vehicle should also be tied down at the four corners of the center section.

If no kinks are present and the misaligned unirail is less than 1" too low, a tie-down behind the damage is usually not required. Pushing up on the end of the damaged unirail should correct the misalignment. See **Figure 15-27**. A push should be set up so it does not crush the unirail. To relieve stresses in the damaged area, spring hammer the unirail while it is under tension.

Front Unirail Kickup

To repair front unirail kickup on one unirail, tie the vehicle down at the four corners of the center section. Block the undamaged unirail. The blocking keeps the undamaged unirail at the proper height during the pull. If the undamaged unirail were not blocked during the pull, it would move down as the other unirail moves down.

With the undamaged unirail blocked so it cannot move, corrective bending takes place as the damaged unirail is pulled down. See **Figure 15-28**. While the damaged rail is under tension, it should be spring hammered. Spring hammering will minimize settle back when pulling force is released. Pull the unirail at least 1/8" beyond the proper location. Release the tension. After pulling, measure again to determine if the rail is in the right place. If necessary, continue to pull—this time 1/4" beyond where it should be—and measure until the rail is in the correct position. **Figure 15-29** shows a different use of blocking to concentrate the force of the pull.

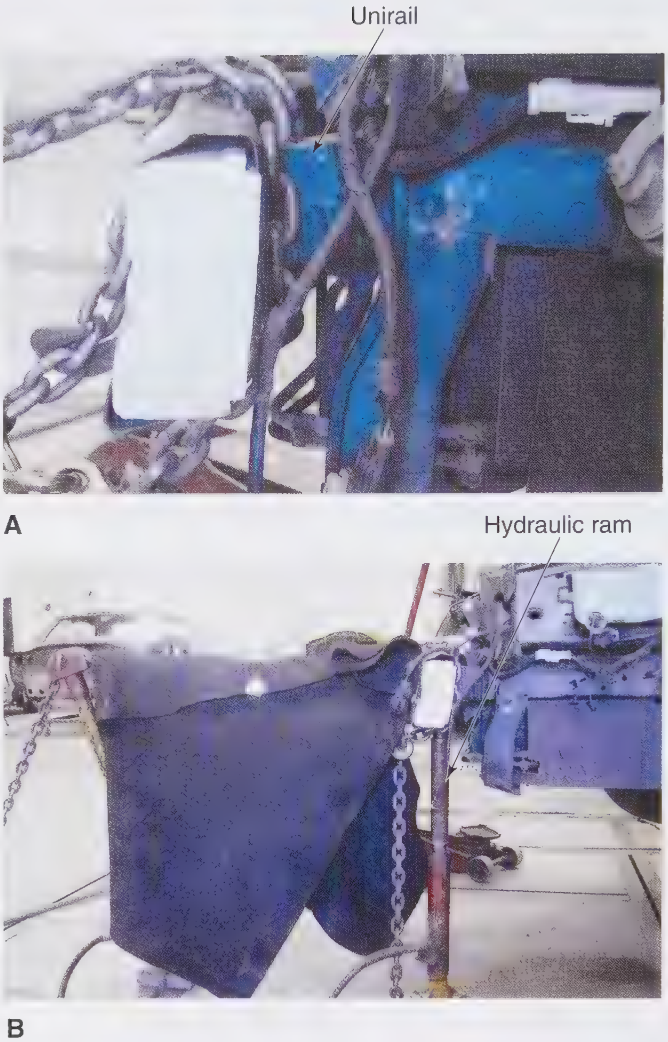


Figure 15-27. *A—This unirail is pushed down behind the radiator support. B—Pushing up with a hydraulic ram corrects the damage.*

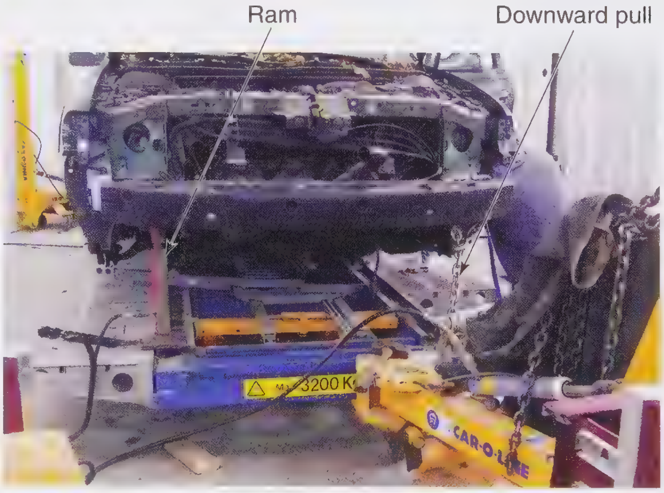


Figure 15-28. *Blocking the undamaged rail using a hydraulic ram concentrates the pull on the damaged rail.*

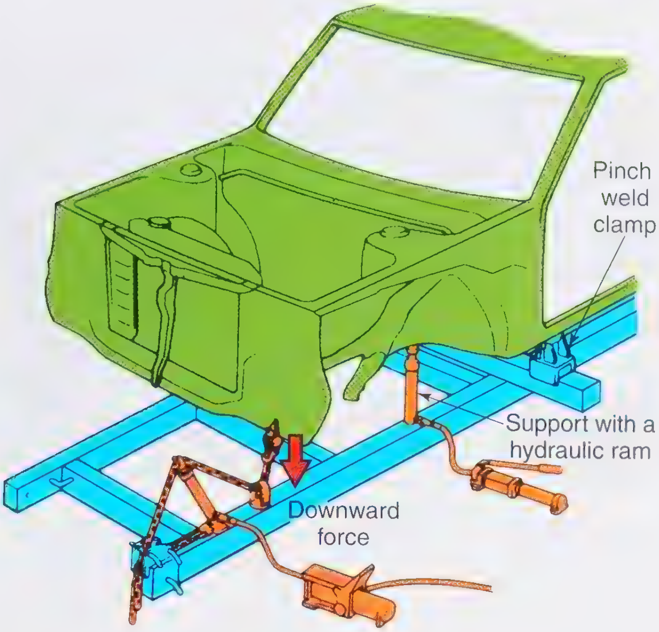


Figure 15-29. *Blocking with a hydraulic ram concentrates the downward pull on the buckle. Without the blocking, the pinch weld clamp would have acted as a pivot point for the downward pull. The pivot point at the pinch weld clamp is too far away from the damage to be useful. (Toyota)*

In this example, a hydraulic ram is used to make a pivot point just to the rear of the damage. The position of the pivot point determines where the down pull will cause the damaged unirail to bend.

Front Unirail Sidesway

A unirail with sidesway is shown in **Figure 15-30**. Notice how one side of the rail is stretched and the opposite side is compressed. During straightening, the hookup should be made on the compressed side. The reason for this is that pulling on the stretched side will only stretch it further. However, pulling on the compressed side will stretch it, restoring the length and shape of the unirail. The vehicle should be tied down at the four corners of the center section before beginning the repair.

The pull should be made in a straight line, out from the rail position. Spring hammer the damaged area as tension is applied.

Kinked rails must be replaced. This is often the case in severe sidesway. Usually sidesway affects both rails. Severe sidesway is shown in **Figure 15-31**. In this example, a combination of forward and side pulls are needed. A light forward pull is made first. Then the area is spring hammered. A light side pull is made next. Again, the area is spring hammered. The forward and side pulls are alternated until the damage is worked out.

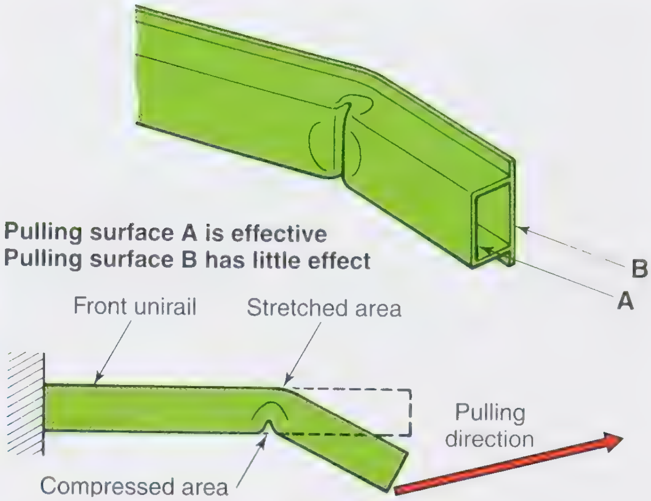

Pulling surface A is effective
Pulling surface B has little effect
B
A
Front unirail
Stretched area
Pulling
direction
Compressed area

Figure 15-30. *Attach the hookup to the compressed, or shortened, side of the rail. Pulling on the short side will restore the length. (Toyota)*

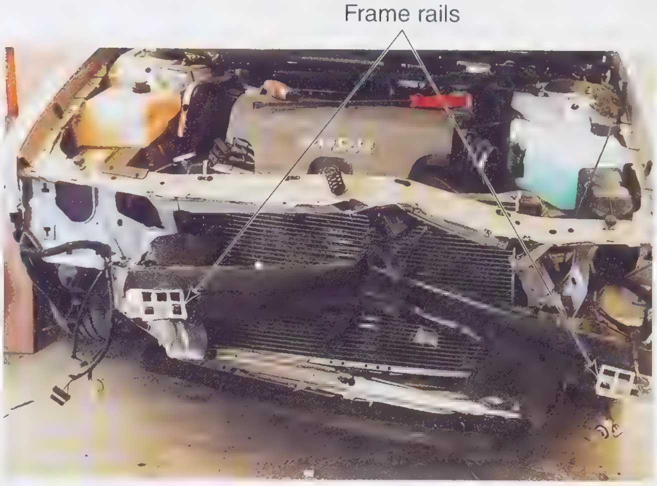


Figure 15-31. *A front impact on the bumper caused sidesway in both frame rails.*

Unirail Mash

When unirail mash occurs, the rail must be lengthened. The vehicle is tied down at the four corners of the center section. Two clamps can be installed, one on either side of the rail, as shown in **Figure 15-32**. Since one side of the rail may be compressed more than the other side, the more compressed side should be pulled first. Apply tension to the more compressed side first. Pull the most compressed side slightly and spring hammer the rail while it is under tension. Once the more compressed side is equal to the other side, both sides can be pulled at once. Apply slight pressure and then spring hammer the damaged areas. Alternate the pressure and spring hammering until the length is restored.

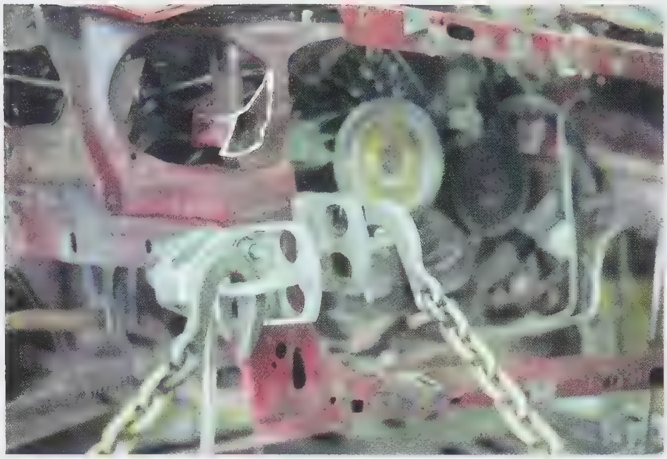


Figure 15-32. *Two clamps are set up to pull mash.*

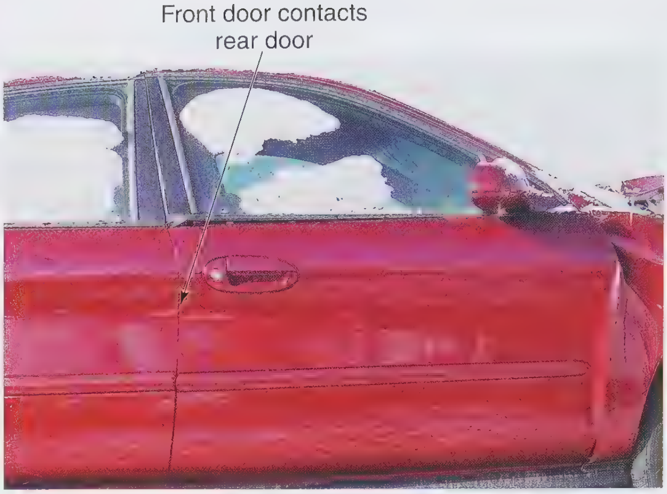


Figure 15-33. *An impact on the front of this vehicle moved the A-pillar and jammed the front door against the rear door.*

A-Pillar Pushed Rearward

When an A-pillar is pushed rearward from a frontal collision, the door will not hang square. The door will drop when opened because damage to the A-pillar will cause misalignment of the door hinges. See **Figure 15-33**. The windshield may be cracked in the corner near the door.

When this type of damage is encountered, the front door should be removed. The collision force may have traveled through the door to the center pillar. Therefore, the center pillar may be damaged as well. After removing the door, carefully check the center pillar for misalignment.

The alignment of the cowl is not a stand-alone operation. It must be done as part of the straightening of the front section. See **Figure 15-34**. The vehicle should be tied down at the four corners of the center section. Pulling forward on B will not move A forward. There is too much resistance in the damaged metal. Therefore, A and B must be moved at the same time. A pull plate bolted to the pillar in place of the door hinges can be used to pull the A-pillar forward. Make sure the frame chain hook is as close to the cowl as possible. A hook placed away from the cowl will make the pull plate twist.

Pull straight ahead. In addition to pulling, the cowl can be moved forward with a hydraulic ram as shown in **Figure 15-35**. The ram is based on the center pillar and set up to push against the cowl. This hydraulic ram method can be used in conjunction with pulling. However, the base of the ram may damage the center pillar if the ram does not rest against a flat surface.

A-Pillar Pushed Inward

A side impact can push an A-pillar inward. In some cases, the impact drives the lower hinge mount area inward. This condition can be easily recognized by a

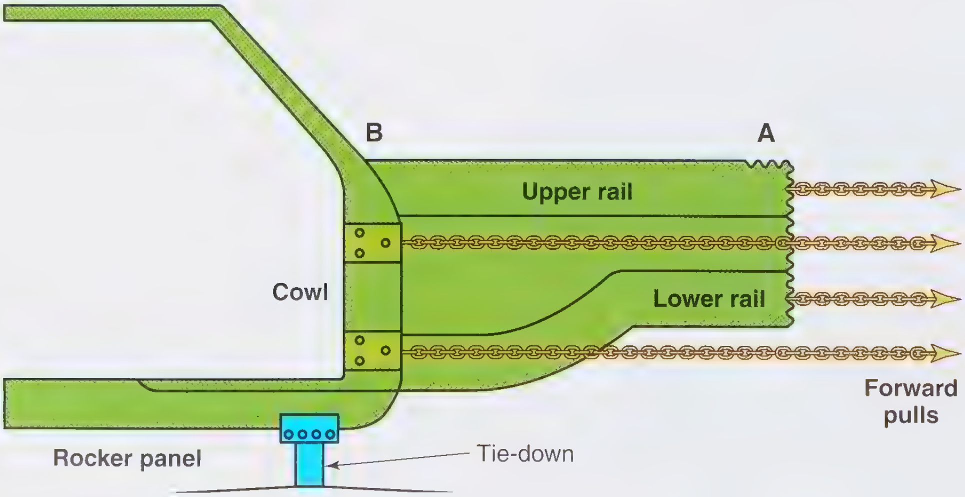


Figure 15-34. *Multiple forward pulls on the cowl and the front of the vehicle will move the cowl into place.*

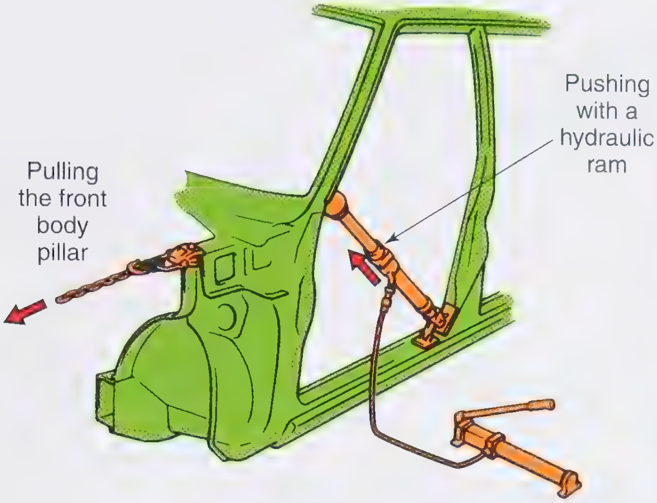

Pulling the front body pillar
Pushing with a hydraulic ram

Figure 15-35. *This setup will push the cowl forward as the front of the vehicle is pulled forward. (Toyota)*

door that sticks out at the top. An A-pillar that is crushed so that both hinge mount areas are pushed inward may not cause the door to stick out at the top. This type of damage can be difficult to repair.

Pillar damage can be either pushed or pulled. Minor damage, where the outer portion of the A-pillar at the lower hinge mount is crushed, can be repaired as shown in **Figure 15-36**. The damaged hinge can be used as a point to pull from. A pull plate can also be bolted to the door hinge caged nuts. Minor damage can be removed with a 10-pound slide hammer.

If hydraulic power is required, the vehicle should be tied down at the four corners of the center section. If the inner panel of the A-pillar is damaged along with the outer panel, pulling on the hinge mounts will not be sufficient. The cross section of an A-pillar may consist of inner and outer panels as well as internal reinforcements. If the internal reinforcement is bent, pulling on the thin outer metal will not provide enough corrective force.

A hook can be set up to push against the inside of the A-pillar. See **Figure 15-37**. A hydraulic ram can also be set up. The base would be at the opposite side of the vehicle. The ram push would require the removal of the dash. Use as many pulls as possible.

A pillar's internal reinforcement is strong. Pushing on the inner panel with a hook or a ram may crush the inside of the A-pillar until it contacts the reinforcement. With this corrective force on the reinforcement, the reinforcement should move. However, this will leave the inner A-pillar damaged. The inner A-pillar may be able to be repaired with dent repair techniques. If not, it should be replaced.

The repair of a damaged A-pillar is shown in **Figure 15-38**. As shown in **Figure 15-38A**, the pillar is moved in and back. The hookups used to straighten

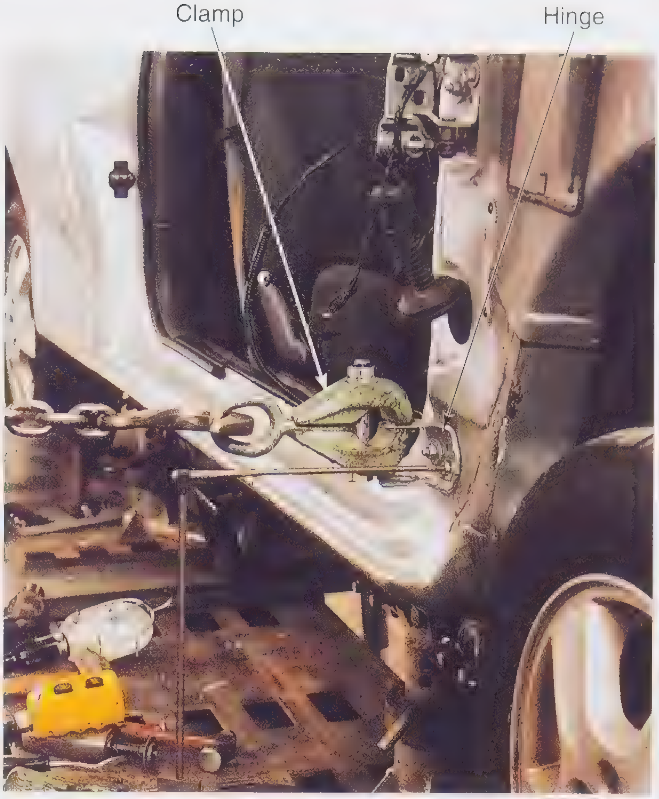


Figure 15-36. *The door hinge mount is pushed in. A hookup is made on the hinge to pull the mount out.*

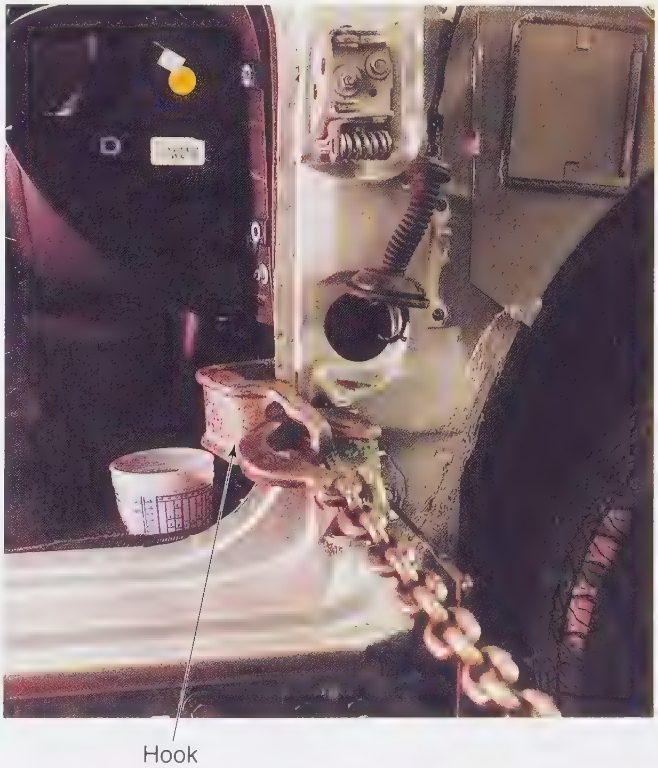


Figure 15-37. *A hook pull actually pushes on the inside of the A-pillar.*

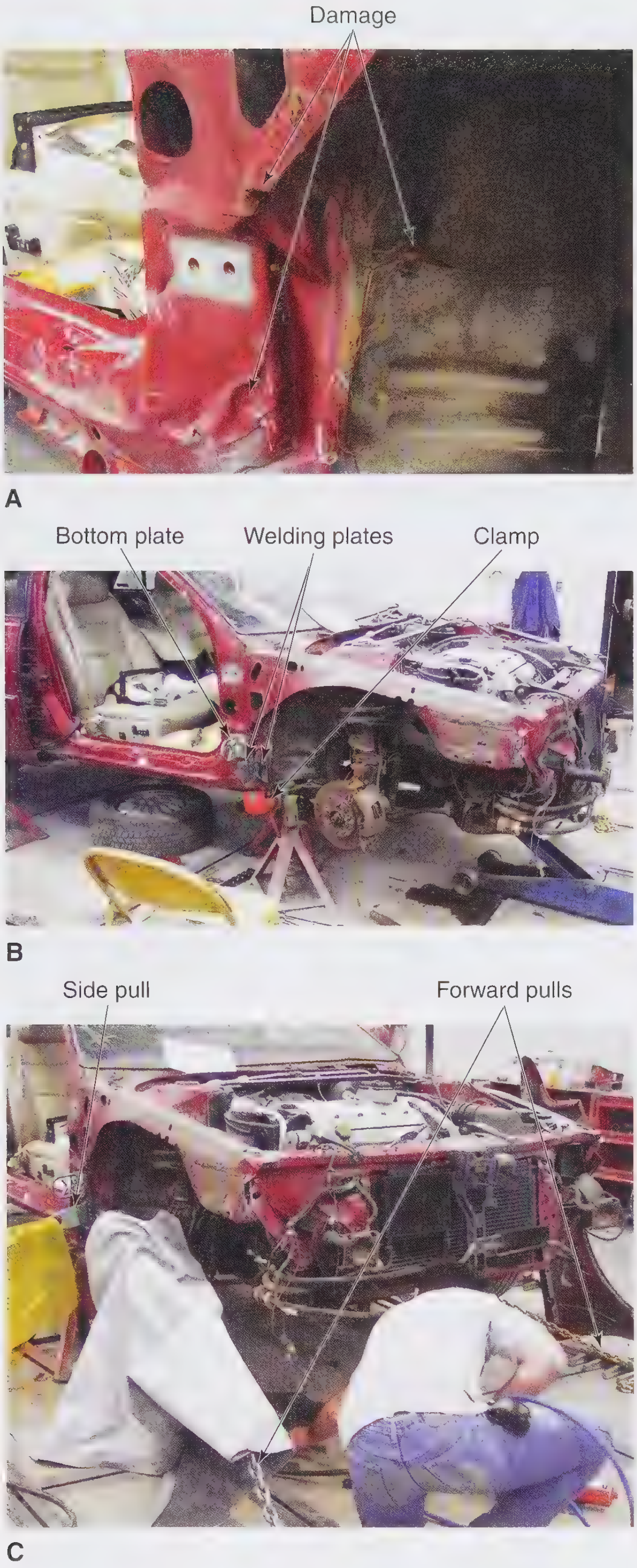


Figure 15-38. *A—This is severe cowl damage, The cowl has been moved back and in. Notice that the damage extends to the wheel house. B—Weld-on and bolt-on plates have been installed to make the pulls. C—Alternating forward and side pulls will remove the damage.*

the A-pillar are shown in **Figure 15-38B**. A bolt-on plate is attached through the lower hinge bolt holes, weld-on plates are placed in buckles to pull sideways and forward, and a clamp is attached to the pinch weld on the rocker panel to pull the rocker panel forward and downward. Pulls are shown in action in **Figure 15-38C**. Alternating slight forward and slight side pulls removed the damage.

Roof Rail Up

A frontal impact may cause a wide gap at the top of the door. **Figure 15-39** shows this type of damage. A hard hit on an upper frame rail will drive the upper frame rail rearward. If enough collision energy is present, the windshield pillar will move up. This damage changes the shape of the door opening and the roof.

Pulling forward on the direct damage usually will not bring the roof down. To lower the roof, a downward pull must be made as the front damage is pulled forward. **Figure 15-40** shows how this procedure is accomplished. The vehicle is secured at the four corners of the center section. The forward pull is made on the upper frame rail. This corrective force starts to move the upper frame rail and indirectly, the windshield pillar in the right direction. Two clamps and a come-along are used to exert the downward pull on the roof. One clamp is placed on the roof pinch weld, and the other clamp is attached to the rocker panel upper pinch weld. The come-along is connected between the clamps. As the come-along is tightened, the roof is brought down. An additional clamp can be installed on the rocker panel under the clamp connected to the come-along. This additional clamp will prevent any upward movement of the rocker panel.

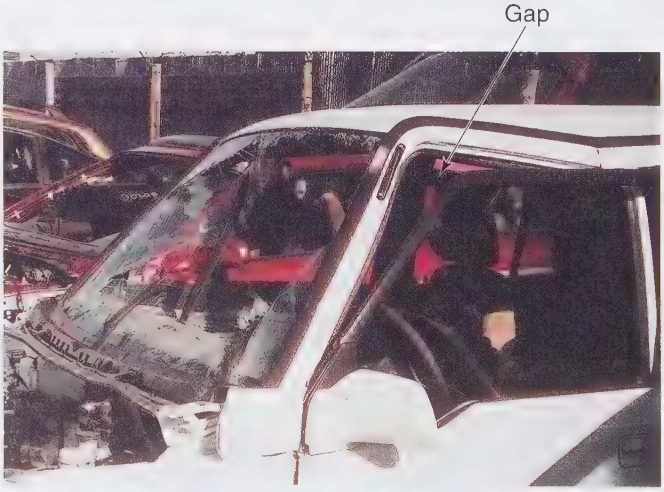


Figure 15-39. *A front impact forced the roof up.*

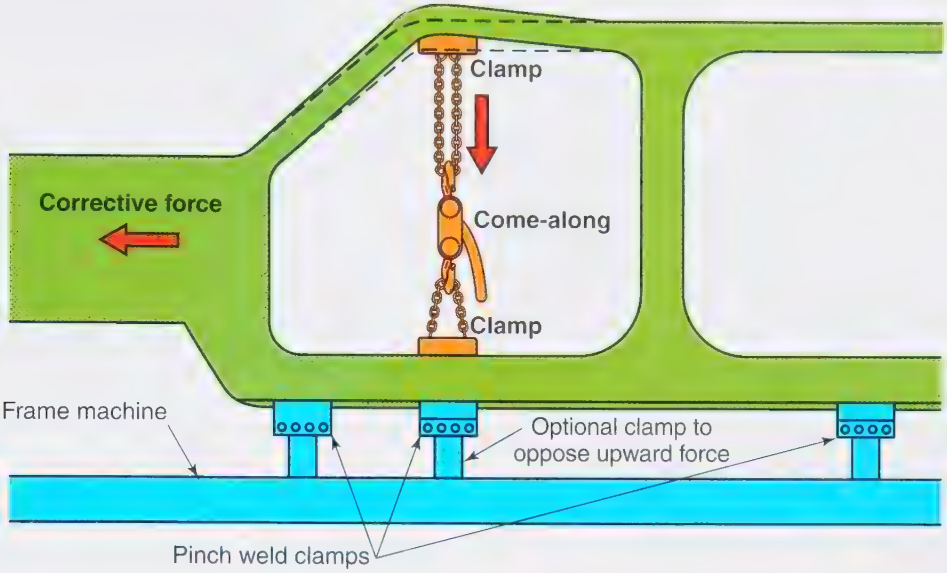


Figure 15-40. *As forward pulls remove the damage to the cowl, the roof is brought down with a come-along.*

Twist

Twist means that the ends of the center section of the vehicle are not level to each other. In minor twist, which may also be called a sag in the center section, one corner of the center section is lower than specifications. This damage may result from a front or rear impact that lowers one corner of the unibody. During repair, the vehicle is tied down at the three undamaged corners. As the direct damage is pulled forward or rearward and upward, a push up is made on the low corner of the center section. The floor in the damaged corner and the rocker panel should be stress relieved while the vehicle is under tension.

In some cases, the front and rear of the center section are not level to each other and both are out of specifications, **Figure 15-41**. During the repair, the rocker panels under the cowl are set to level. This means that the pinch weld clamps are set at the same height and tied down to the frame machine. This forces the low rocker panel upward. At the rear of the center section, the low rocker panel is set to the same height as the cowl with a pinch weld clamp tied to the frame machine. This forces the low rocker panel at the rear of the center section upward. A downward pull is made on the high rocker panel at the rear of the center section. The downward pull moves the corners of the center section of the vehicle back to their specified heights. The entire floor and rocker panels should be spring hammered while under tension to relieve stress.

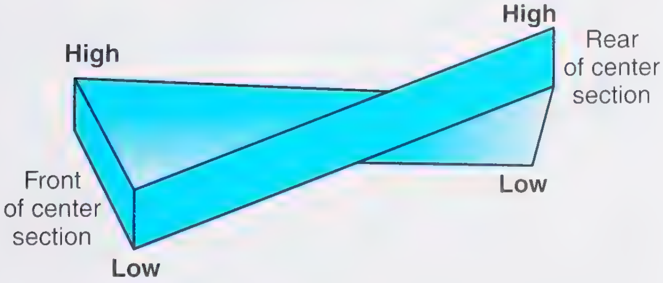


Figure 15-41. *In twist, the front of the center section is not level with the rear of the center section.*

Center Pillar In

A center pillar consists of inner and outer panels and internal reinforcements. A center pillar damage sequence is shown in **Figure 15-42**. The pillar is moved in from a side impact. The inward movement of the center pillar takes the bow out of the center pillar. This lengthens the pillar slightly and puts upward force on the roof and downward force on the rocker panel. The roof, which is weaker than the rocker panel, may move up slightly. Continued application of impact force shortens the center pillar, pulling the roof down as the center pillar moves in.

Center pillar damage is similar to A-pillar damage in that the door alignment will be off if the hinge mounts are moved. Minor damage to the outer panel of the center pillar, which does not cause the center pillar to move in at all, can be repaired with a pull plate bolted to the hinge caged nuts. A 10-pound slide hammer may provide enough force to repair the damage. Damage that moves the entire center pillar inward will require a pull, push, or both. To pull out a center pillar, remove the trim and seat belts from the damaged pillar. Tie down

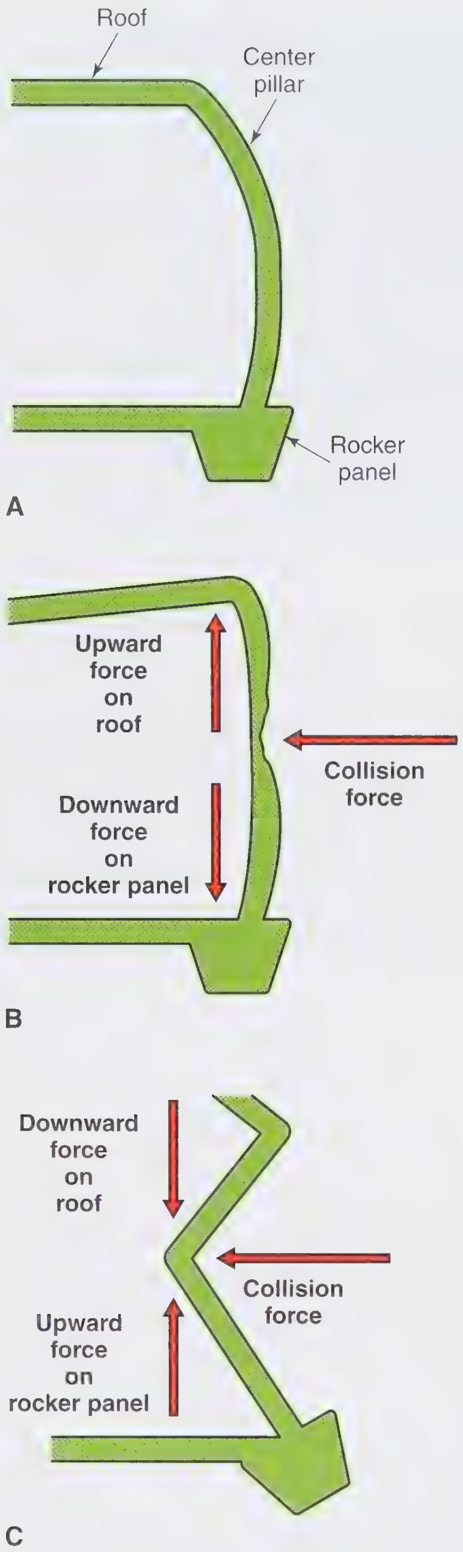

Roof
Center pillar
Rocker panel
A
Upward force on roof
Collision force
Downward force on rocker panel
B
Downward force on roof
Collision force
Upward force on rocker panel
C

Figure 15-42. *A—This is an undamaged center pillar. Note the bow in the pillar. B—Collision impact first pushes in on the center pillar, straightening out the bow. C—Continued force shortens the center pillar, pulling the roof down and the rocker panel up.*

the center section of the vehicle in the four corners. The hookup can be a nylon pull strap with a plate to prevent collapse of the center pillar. Make sure the strap and plate are placed at the buckle. This hookup will remove the buckle in the inner panel of the center pillar. To remove the buckle in the outer panel of the center pillar, weld a pull plate to the buckle. Pull the outer panel slightly; then the inner panel. Spring hammer to relieve the stress. Alternate the pulls and relieve the stress.

If the roof is down, an upward push should be made with a hydraulic ram based on the floor. Push up on the reinforcement that connects the roof and center pillar. The upward push should begin before the pulls on the center pillar. Alternate the push and the pulls to gradually pull out the center pillar and raise the roof. See **Figure 15-43**. If the rocker panel is rolled out from the collapse of the center pillar, pull the pinch weld tie-down toward the center of the vehicle to correct the damage. If the roof is up, the pulling on the center pillar will bring it down.

To push out the center pillar, the front seats should be removed. A hydraulic ram should be set up at the base of the undamaged center pillar. Position the ram to push on the inner panel at the damage. See **Figure 15-44**. Then push out on the center pillar. If the roof is down, either set up another ram to push up on the roof or reposition the ram to push up and then out. Pushing will not correct damage to the outer panel of the center pillar.

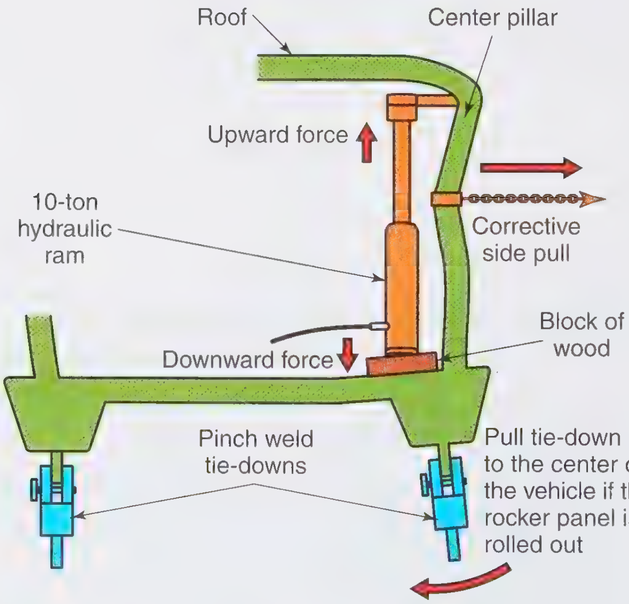

Roof
Center pillar
Upward force
10-ton hydraulic ram
Corrective side pull
Block of wood
Downward force
Pinch weld tie-downs
Pull tie-down to the center of the vehicle if the rocker panel is rolled out

Figure 15-43. *Pushing up on the roof, pushing down on the rocker panel, and pulling out on the center pillar will remove the damage.*

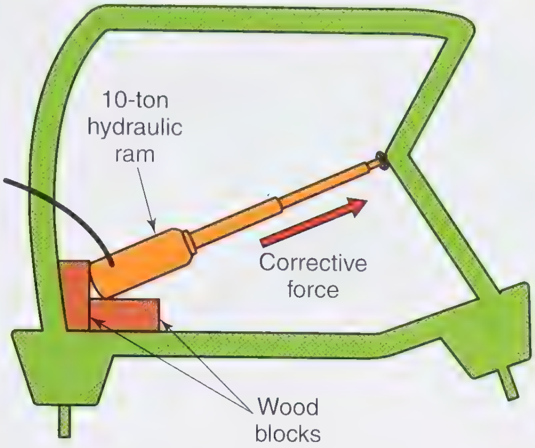


Figure 15-44. *Pushing out with a hydraulic ram is the first step in this repair. The ram must be moved to push up on the roof and down on the rocker panel. Alternating between these two pushes will correct the damage.*

Rocker Panel In

A rocker panel is a complex part. It consists of inner and outer panels, as well as internal reinforcements. A side impact may bend the rocker panel in, shortening its length. The direct damage to the outer rocker panel is readily visible. The damage to the inner rocker panel, the internal reinforcement, and the floor may not be as apparent. In severe damage, the rocker panel is shortened so much that the end sections of the vehicle rotate toward the shortened side. See **Figure 15-45**. Lengthening the rocker panel and repairing any adjacent or attached panels can correct this type of damage.

Pushing or pulling can lengthen a shortened rocker panel. In pulling, hookups are made at either end of the damaged rocker panel. One pull is made forward, and one pull is made rearward. In pushing to lengthen the rocker panel, pinch weld clamps are placed at either end of the damaged rocker panel. A hydraulic ram is placed in between the clamps. As the ram is extended, the clamps are pushed apart, lengthening the rocker panel. As the rocker panel is lengthened, the buckle in the outer rocker panel can be pulled out with a side pull. **Figure 15-46** shows the pulls used to correct minor rocker panel damage. In this collision, the center pillar and rocker panel were moved in. Notice the bolt-on plate used to pull the center pillar. Clamps placed on either side of the center pillar on the door opening pinch welds pull the rocker panel damage.

In severe rocker panel damage, where the end sections are rotated toward the damage, the end sections should be pulled back into place as the rocker panel is lengthened. **Figure 15-47** shows pulls attached to the rocker panel pinch weld clamps to lengthen the rocker panel. Pulls on the end sections rotate the end sections back into position. In this repair, the end sections are pulled slightly and then the rocker panel is pulled slightly. The end sections are pulled more, the rocker panel lengthened more, and then a side pull is made to remove the buckle from the rocker panel.

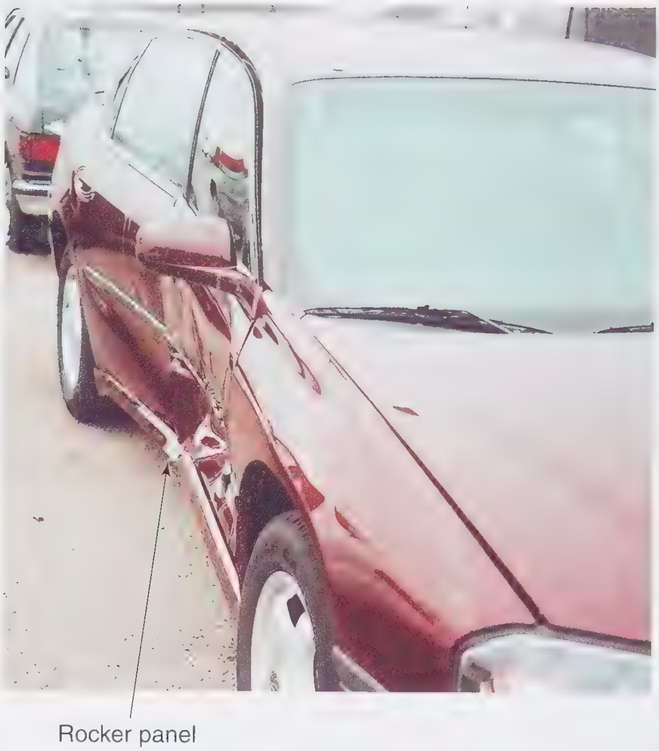


Figure 15-45. *The rocker panel is pushed in, shortening the length.*

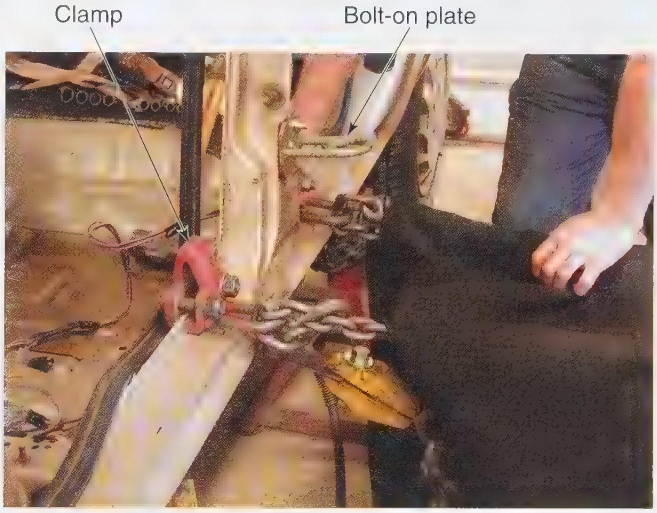


Figure 15-46. *A combination of weld-on and bolt-on plates and clamps are used to pull out this center pillar and rocker panel.*

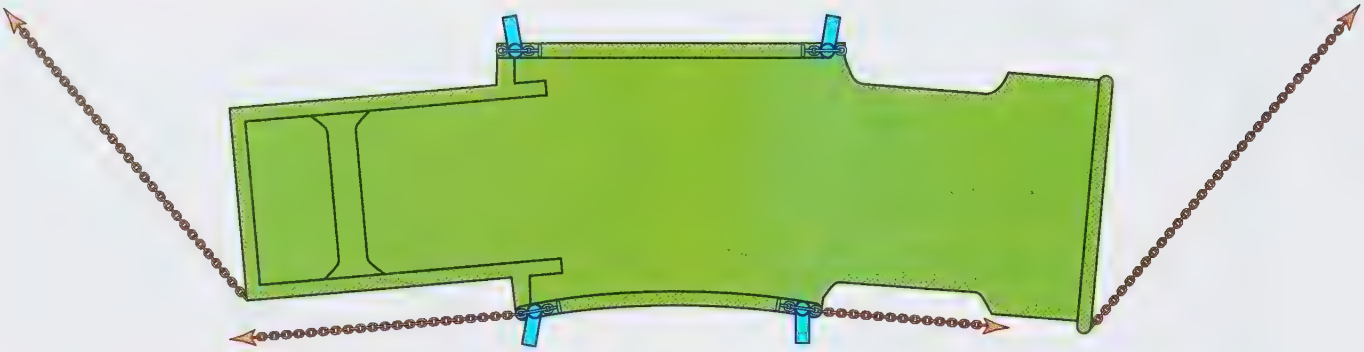


Figure 15-47. *A double stretch pull on the rocker panel, along with pulls on the end sections and the center section, will remove the severe sidesway. (Chief Automotive Systems)*

The end sections and the rocker panel should be correctly aligned before pulling out on the center pillar. **Figure 15-48** shows a hydraulic ram set up to push apart the pinch weld clamps to lengthen the rocker panel as the center pillar is pulled out.

In many cases, pulling on the rocker panel will not bring the floor with it. The buckles in the floor may be so strong that the rocker panel breaks away from the floor during the pull. To prevent this, the rocker panel should be lengthened as much as possible. The damaged portion of the rocker panel is then cut away so the floor can be clamped directly. A wide jaw clamp or several narrow jaw clamps are attached to the floor. A side pull is made on the clamps. The rocker panel will need to be replaced after the pulling is complete.

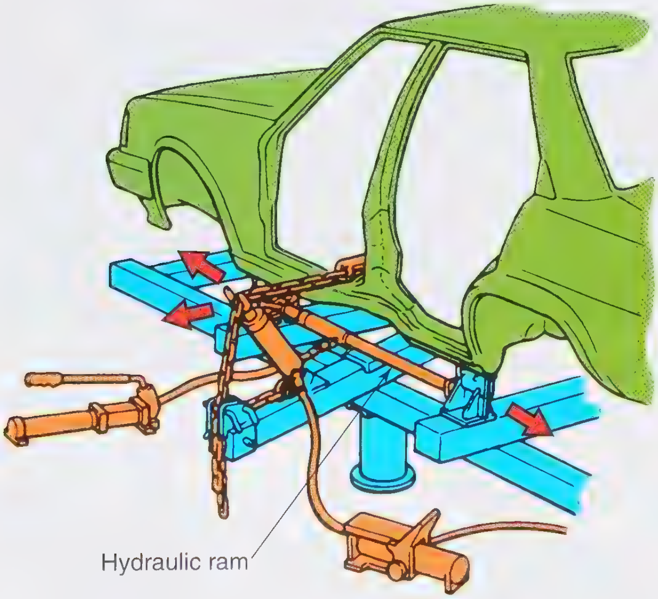


Figure 15-48. *A hydraulic ram is set up between the rocker panel pinch weld clamps to push the clamps apart while the center pillar is pulled out. (Toyota)*

Roof Down

The pillars that support the roof can be damaged in a rollover accident. If the roof panel will be replaced, remove the roof panel before straightening. With the roof panel out of the way, the roof header and bows will be accessible. A rollover may also cause a twist in the center section of the vehicle. When this is the case, the twist should be repaired first. If pulls are made, the vehicle should be tied down at the four corners of the center section. If pushes are used, the vehicle does not need to be tied down. **Figure 15-49** shows a situation where one A-pillar has been moved inward and the opposite A-pillar has been moved outward. A side pull can be made at the direct damage to bring the windshield opening into alignment. In this repair, a nylon strap is wrapped around the windshield pillar. The windshield must be removed before repairs are made. While the roof is under tension the roof header and bows should be spring hammered. A push can also be made from inside the vehicle.

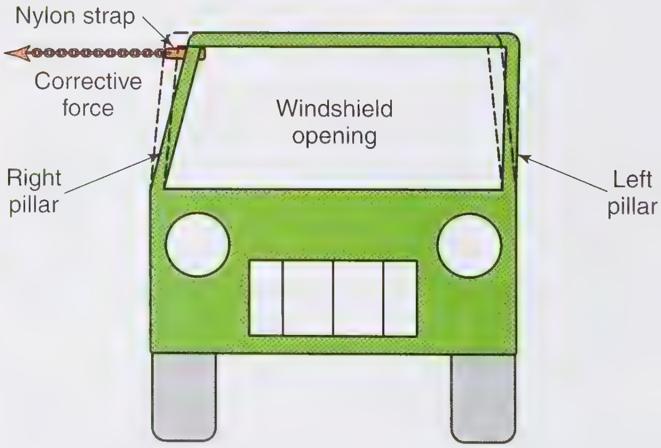


Figure 15-49. *This windshield pillar has been moved over. Pulling on the damaged side will bring the roof back into alignment.*

NOTE

When pushes are made from inside the vehicle, it may be necessary to remove the seats.

If the A-pillar is pushed back, the damage can also be corrected by pulling or pushing. In this case, a forward pull can be made or a push can be set up to move the pillar forward.

Rear Unirail Damage

A rear impact can bend a rear unirail and buckle the quarter panel and trunk floor. If the unirail is straightened, much of the damage in the quarter panel and trunk floor can be worked out. **Figure 15-50** shows the hookup and pull used to remove the rear end damage. The bolt holes for the rear bumper, as well as the trunk floor lip, are used for hookups. As the unirail is lengthened, the trunk floor and quarter panels should be spring hammered. The trunk floor has many convolutions, so it may take considerable time to achieve stress relief.

If the rear unirail is kinked more than a foot in front of the direct damage, pulling on the kink may be difficult. This is because pulls are more effective when the hookup is close to the kink. Pulling on the direct damage simply may not put enough force on the kink. When this is the case, the hookup must be placed on the frame rail just behind the kink. If there is a frame hole available, a hook can be inserted into the hole. The hole can be reinforced by making a MIG weld bead around it. Another method of pulling on the kink is to use a sandwich clamp. The upper half of the sandwich clamp is inserted into the frame rail by feeding it through the hole where the bumper mounts. The lower half of the clamp is bolted to the upper half through a hole drilled in the rail. The clamp has teeth to bite into the rail as it is tightened. A chain is attached to the clamp and a pull is made. See **Figure 15-51**. By pulling out the kink, the trunk floor and quarter panel can be straightened. Simply cutting out the damaged rail will not straighten the trunk floor. Once the rail, quarter panel, and trunk floor are straightened, the kinked rail can be removed for sectioning.

Figure 15-52 shows a unibody vehicle that was parked and hit on the passenger's side rear, pushing the driver's side rear into an adjacent vehicle. The trunk floor was compressed as the left and right rear unirails

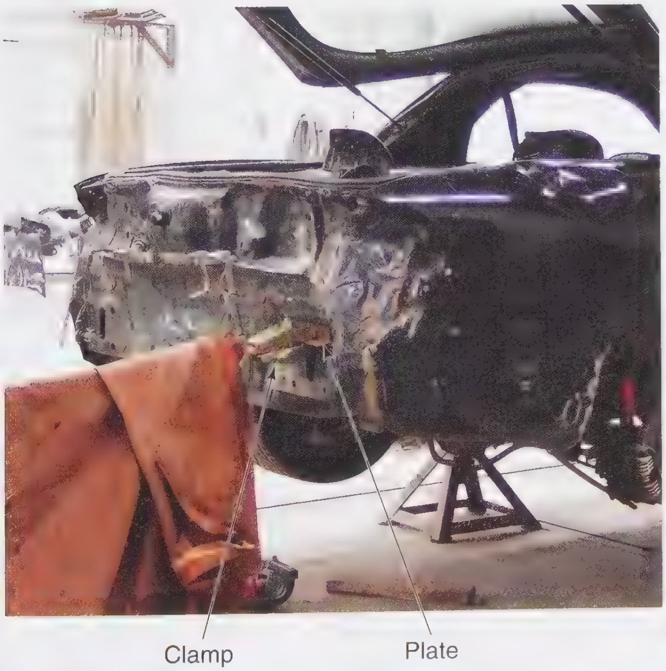


Figure 15-50. *A plate bolted to the rear bumper holes hooks up the pull of this rear hit vehicle. Notice the damage to the quarter panel.*

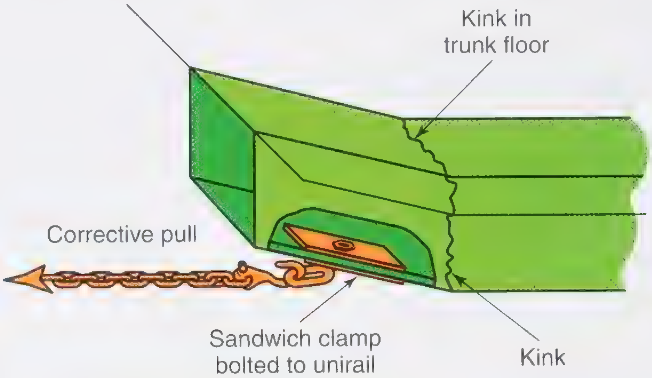


Figure 15-51. *The sandwich clamp is positioned inside the unirail just to the rear of the kink. This will concentrate the pull force on the damage.*

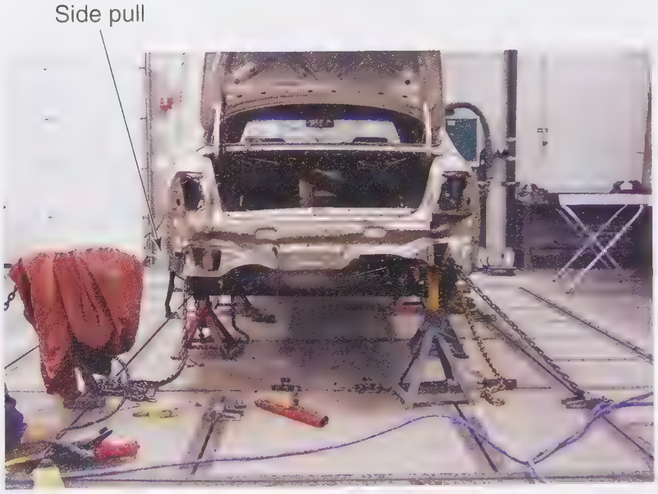


Figure 15-52. *A side pull on a weld-on plate hookup moves the left side of the vehicle to the left.*

were pushed together. This photo was taken during repair. The passenger side and driver's side unirails have been pulled to the sides. The passenger side unirail is blocked with a jack stand and held in place with a chain wrap tie-down. A pull is being made on a weld-on plate to move the driver's side quarter panel. Notice that the driver's side unirail needs to move down. The jack stand blocking will help concentrate the force of the down pull on the driver's side unirail.

Access Windows

Access to the rear side of buckles in unirails is limited. A common solution to this problem is to cut an ***access window*** in the rail so a rod, hammer, or dolly can be inserted to work the buckle. The window is cut out with a cut-off tool. After the buckle is removed, the window that was cut out is welded back in place. In mild steel unirails, the welding and heating is not a problem. However, in a high-strength unirail, the welding of the four sides of the window will compromise the design strength of the unirail. Do not cut access windows in high-strength steel. **Figure 15-53** shows a unirail with a slight kink. Pulls on the unirail will not remove the indented area near the oval hole. Cutting a window in the opposite side of the unirail will allow access to the back side to tap out the low area. See **Figure 15-54**.

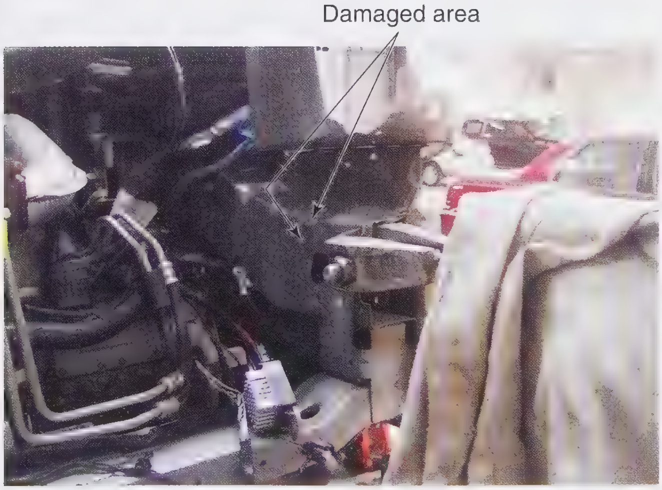


Figure 15-53. *Notice the slight kink in the corner of the unirail and the low area near the oval hole on the inner portion of this unirail. There is not enough access to reach this damage from the front of the unirail.*

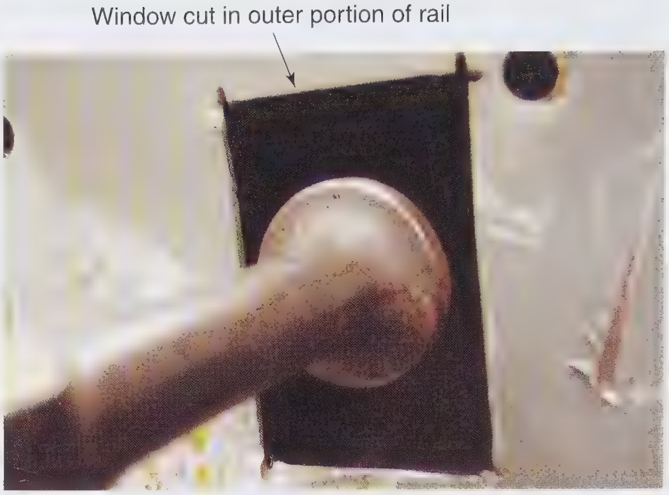


Figure 15-54. *A window is cut in the outer portion of the unirail so a hammer can reach in and tap the low area out.*

Summary

- Kinked high-strength steel parts must be replaced because kinks weaken the grain structure of the steel.
- Unibody straightening involves the gradual removal of many small stresses in the damaged unirails or structural parts.
- Because a unibody is designed to absorb collision energy, slight distortion may be found in areas far from the impact.
- Unibody repair requires direct access to structural parts in order to find all the damage, hold the vehicle in place, attach pulls, and relieve all the stress in the unibody.
- Obvious damage is fairly easy to identify. Subtle damage, on the other hand, may be missed during a casual damage inspection.
- All damage causes stress in the steel panels. The stress is a rearrangement of the regular pattern in the grains of the steel.
- Because it is impossible to look at a structural panel and determine if it is made from high-strength steel, treat all structural panels as if they are made of high-strength steel.
- Tie-downs are used to hold a vehicle in place during pulling and pushing. The tie-downs must be stronger than the pull. Most unibody vehicles are tied down by pinch weld clamps placed on the bottom of the rocker panels.
- Blocking can be used to maintain the height of an area during a pull, as well as to change the height of an area or act as a pivot point during a down pull.

- Hookups are used to attach the pull to the vehicle. Multiple hookups spread the force of the pull over a wider area.
- Severe buckles cannot be simply hammered out. Controlled movement of the damaged metal and restoration of the grain pattern will unlock the buckle.
- Pulls are used to return damaged parts to their original positions. A pull will always attempt to exert a force in a straight line between the origin of the pull and the tie-down.
- There are several types of pulls used to repair unibody damage. The type of pull used depends on the type of damage being repaired.
- Overpulling means that the damaged panel is moved slightly beyond the correct location to account for settle back.
- Settle back means that once the tension is released the panel returns to a position that indicates damage.
- In some cases, pushes are used to repair unibody damage.
- To properly repair a unibody vehicle, all the steel grain must be returned to the original undamaged state. This process is called stress relief. There are two methods that can be used to relieve stress: spring hammering and heat.
- One way to determine the temperature of a heated panel is to use a heat crayon. An infrared, remote sensing thermometer can also be used to determine the temperature of a heated panel.

Review Questions

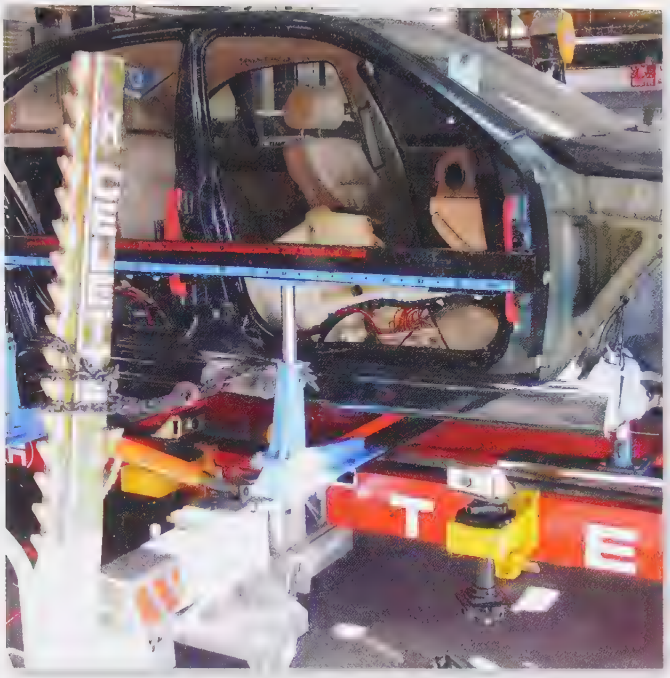
Please do not write in this textbook. Place your answers on a separate sheet of paper.

1. Because a unibody is designed to ______ collision energy, distortion may be found in areas far from the point of impact.
2. Why does unibody repair require direct access to structural parts?
3. ______ damage can consist of out-of-level dimples, raised areas between spot welds, or split caulking.
4. How many tie-downs are used to anchor the center section of a unibody vehicle?
5. Explain the value of multiple hookups.
6. A pull will attempt to make a straight line between the pull and the ______.
7. A forward pull can correct sidesway. True or False?
8. An upward pull is used to correct ______.
9. During a pull, the ram pressure gauge reads 3000 psi and nothing is moving. What should the technician do?
10. What is the purpose of the stress relief process?
11. The energy to rearrange the grains of steel can be provided by ______ or ______.
12. Spring hammering is done before tension is applied. True or False?
13. When stress relieving, the technician should start at the direct damage and work toward the indirect damage. True or False?
14. ______ steel panels can be damaged by excessive heat.
15. When a damaged unirail is heated, an area twice the size of the buckle should be heated. True or False?
16. The maximum temperature that a high-strength steel panel can be heated to is 1200° F. What temperature of heat crayon should be used?
17. Explain why the undamaged front unirail is blocked when repairing kickup on the other front unirail.
18. When repairing front unirail sidesway, the hookup should be made on the stretched side. True or False?
19. Unirail mash repair involves ______ the rail.
20. ______ is present when the ends of the vehicle's center section are not level with each other.

ASE-Type Questions

1. Technician A says that kinked high-strength steel panels must be replaced. Technician B says that bent high-strength steel panels must be replaced. Who is right?
   (A) A only.
   (B) B only.
   (C) Both A and B.
   (D) Neither A nor B.
2. Technician A says that blocking can be used to maintain the height of an area during a pull. Technician B says that blocking can be used to change the height of an area during a pull. Who is right?
   (A) A only.
   (B) B only.
   (C) Both A and B.
   (D) Neither A nor B.
3. Which of the following pulls are parallel to the centerline?
   (A) Angle pulls.
   (B) Side pulls.
   (C) Forward pulls.
   (D) Upward pulls.
4. All of the following pulls can be used to straighten sidesway EXCEPT:
   (A) a forward pull.
   (B) a downward pull.
   (C) an angle pull.
   (D) a double stretch pull.

5. A unibody vehicle has severe A-pillar damage. Technician A wants to make one pull on the lower hinge. Technician B wants to make multiple pulls to remove the damage. Who is right?
   (A) A only.
   (B) B only.
   (C) Both A and B.
   (D) Neither A nor B.
6. Technician A wants to spring hammer and then apply tension. Technician B wants to apply heat and then apply tension. Who is right?
   (A) A only.
   (B) B only.
   (C) Both A and B.
   (D) Neither A nor B.
7. Technician A says that spring hammering should be done with a sledge hammer. Technician B says that before pulling, all buckles should be hammered down. Who is right?
   (A) A only.
   (B) B only.
   (C) Both A and B.
   (D) Neither A nor B.
8. When spring hammering, Technician A taps on spot welds. Technician B taps on convolutions. Who is right?
   (A) A only.
   (B) B only.
   (C) Both A and B.
   (D) Neither A nor B.
9. Excessive heating of high-strength steel causes the grain size to ______.
   (A) shrink
   (B) grow
   (C) remain the same
   (D) None of the above.
10. Heat must be applied to a unirail. Technician A wants to use an oxyacetylene torch with an oxidizing flame. Technician B wants to use a heat crayon with a temperature rating above the maximum heating temperature of the steel. Who is right?
   (A) A only.
   (B) B only.
   (C) Both A and B.
   (D) Neither A nor B.
11. A unirail has kickup. How many tie-downs should be placed in the center section?
   (A) One.
   (B) Two.
   (C) Three.
   (D) Four.
12. A unirail has sidesway. Technician A wants to make the hookup on the stretched side. Technician B wants to make the hookup on the compressed side. Who is right?
   (A) A only.
   (B) B only.
   (C) Both A and B.
   (D) Neither A nor B.
13. A front hit unibody has a wide gap between the roof and the door. Technician A says that pulling on the lower front frame rail will correct the damage. Technician B says that the roof should be pulled down separately as the front damage is straightened. Who is right?
   (A) A only.
   (B) B only.
   (C) Both A and B.
   (D) Neither A nor B.
14. A unibody center section has one high corner. How many tie-downs should be used in the center section to correct this damage?
   (A) One.
   (B) Two.
   (C) Three.
   (D) Four.
15. Rocker panel length has been shortened by a side impact. The best way to straighten this vehicle is to ______.
   (A) shorten the rocker panel
   (B) push it out from inside the vehicle
   (C) lengthen the rocker panel
   (D) None of the above.



Chapter 16

Full-Frame Repair

Objectives

After studying this chapter, you will be able to:

- Make the proper tie-downs to repair various types of full-frame damage.
- Make the proper hookups to repair various types of full-frame damage.
- Make the proper pulls to remove various types of full-frame damage.
- Properly relieve stress in a damaged full frame.

Technical Terms

anchoring
bar hookup
blocking
chain basket hookup
chain wrap hookup
chain-and-block tie-down
combination damage
counterpoint tie-down
full-frame clamps
hook-and-block tie-down
lever
multiple pulls
overpulling
pivot-point tie-down
spring back
stress relief
widening

Introduction

This chapter explains how to repair full-frame damage. Full-frame repair can be complicated when viewed as an entire project. However, if the project is broken down into individual steps, the steps themselves are relatively simple.

To better understand the basic idea behind full-frame repair, bend two pieces of wire so there is a loop at one end of each and hook these loops together. Then bend one of the wires in the center at an angle of approximately 60°. Hold this wire in your left hand and hold the other wire in your right hand. See **Figure 16-1**. Pull on the wire in your right hand while holding the wire in your left hand stationary. Notice how the bent piece of wire straightens. The bent piece of wire represents the bent frame, the straight wire is the frame chain, and the loops are the hookup. Your left hand represents the tie-down, and your right hand is the pull.

As you will notice from this demonstration, the pull always tries to make a straight line between itself and the tie-down. The force of the pull acts on the tie-down. Therefore, the tie-down must be stronger than the pull. If it is not, the pull will move the tie-down rather than the damage.

A simple ***lever*** is shown in **Figure 16-2**. It consists of a bar that rests on a fulcrum, or pivot point. The lever is used to transmit force. The ends of the bar are located at points *A* and *C*. The fulcrum is at point *B*. If point *C* is moved down, point *A* moves upward. If a weight is placed on point *A*, pushing down on point *C* will raise the weight. If the distance between points *B* and *C* is increased, a greater weight can be lifted with the same amount of force at *C*.

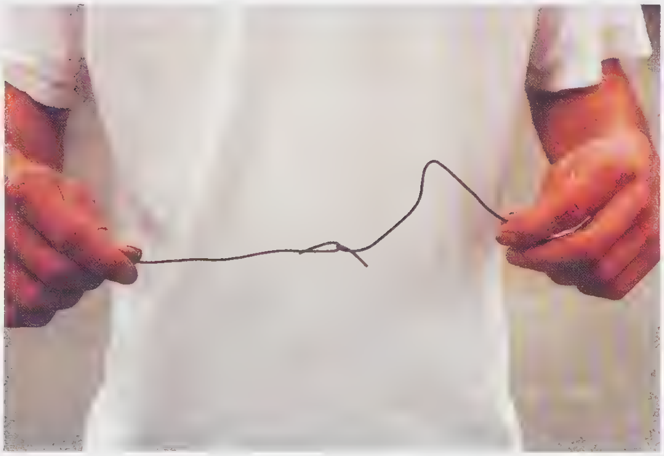


Figure 16-1. *The wire in the technician's left hand represents a bent frame, and the wire in his right hand represents the pull.*

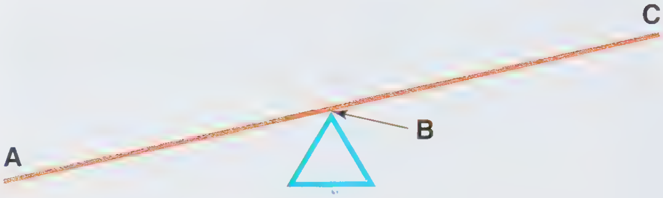


Figure 16-2. *This is a lever. Pushing down at C causes A to rise.*

The basic operation of a lever can be applied to frame repair. The bar represents the frame rail and the fulcrum represents the tie-down. **Figure 16-3** shows a bent bar representing a bent frame. The tie-down is at the bend (*B*). If a downward force is applied at point *C*, point *A* will naturally move upward. If another tie-down is made at point *A*, immobilizing the bar from *A* to *B*, the downward force at point *C* will act on *B*. Of course, the tie-downs at *A* and *B* must be stronger than the force applied to point *C*. The force at *B* is determined by the amount of force applied at *C* and the distance between points *B* and *C*. The bent bar will straighten when the force at *B*, which results from pushing down at *C*, is greater than the strength of the bend at *B*.

Basic Frame Straightening Operations

The sequence of operations that should be used whenever repairing a full-frame vehicle is as follows:

1. Analyze the damage.
2. Remove parts that will interfere with the repair.
3. Tie down the vehicle or frame so it does not move.
4. Make hookups to attach pulls to the frame.
5. Make pulls to remove damage.
6. Relieve stress as pulls are made to prevent additional damage.

The following sections detail each of these basic operations.

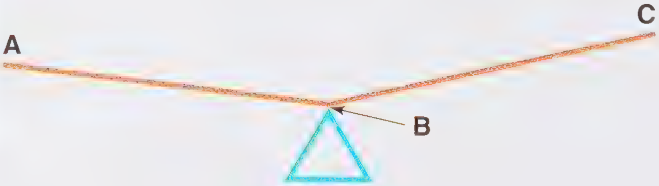


Figure 16-3. *This is also a lever with a bend at B. Pushing down at C causes A to rise.*

Damage Analysis

Careful measurement will allow you to identify misaligned portions of the vehicle's frame. Frame repairs should not begin until all damage has been identified. With some computerized measuring systems, two to four undamaged points are needed to calibrate the system. If undamaged points are not available, preliminary pulls must be made to align enough points to set up the measuring system.

The tolerances for a full-frame vehicle are ±1/4" (±6 mm) for linear measurements and ±1/2" (±12 mm) for x-checks. If measurements are within these tolerances, the measuring points are considered undamaged. Once the vehicle has been measured, the technician can draw a damage diagram. See **Figure 16-4**. If a computerized measuring system is used, the computer screen or printout can be examined to determine the extent of the damage.

After taking the necessary measurements, you should think the repair through. Where is the damage? How does the frame need to be moved in order to be in alignment? Where should the frame be held and how should it be pulled? These are questions that should be answered before beginning the repair.

Part Removal

Various parts must often be removed from a vehicle during full-frame repair. By removing parts, the frame can be made accessible. Parts that may need to be removed include the front or rear bumpers, fenders, hood, radiator support, radiator, condenser, front cross members, pickup truck box, running boards, and gas tank. See **Figure 16-5**.

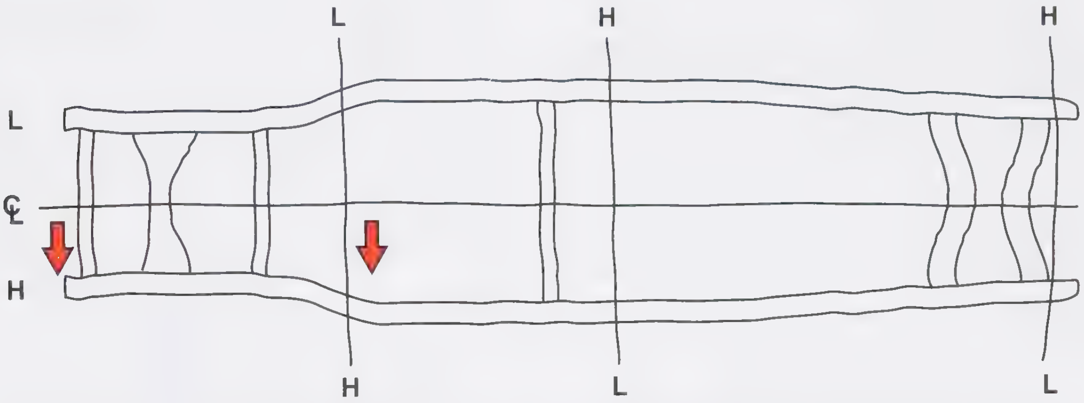


Figure 16-4. *The damage diagram shows that this full-frame vehicle has twist and sidesway.*

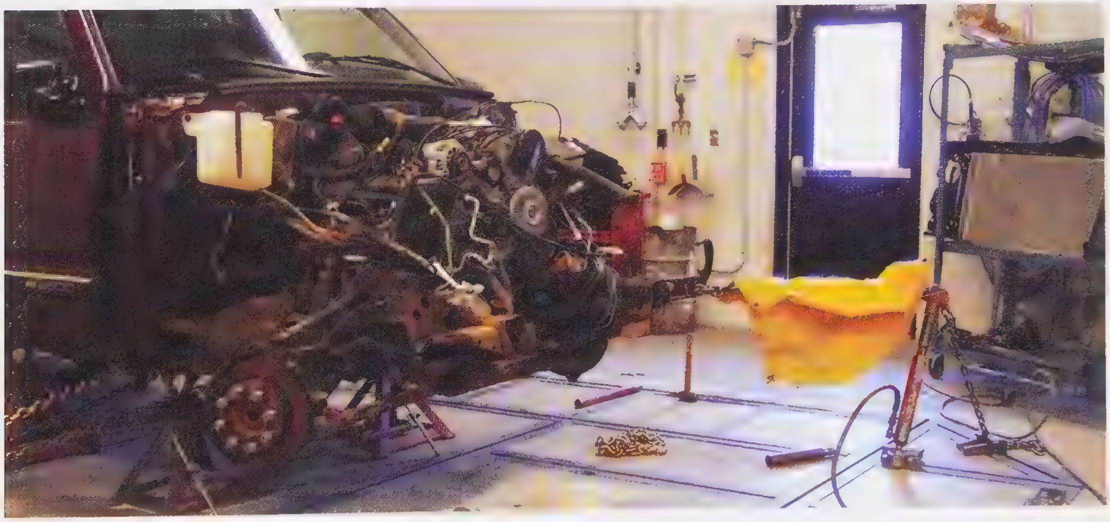


Figure 16-5. *The hood, front bumper, fenders, radiator support, radiator, condenser, wheels, and front differential housing were removed from this pickup truck.*

To make room for tie-downs or hookups, some parts can be loosened and moved out of the way. They generally do not have to be removed completely. These parts include gas lines, brake lines, and electrical wiring, as well as the cab, and steering and suspension components.

Tie-Downs

Tie-downs prevent movement of the vehicle so that pulls move the damage and not the entire vehicle. In addition to holding the vehicle in place, some tie-downs are positioned to help correct the damage by creating pivot points.

There are two types of tie-downs, pivot-point tie-downs and counterpoint tie-downs. A ***pivot-point tie-down*** is positioned at the damage. This type of tie-down functions like the fulcrum shown in **Figure 16-6**. Pivot-point tie-downs prevent movement so the frame will bend at the desired location during the pull.

A ***counterpoint tie-down*** is positioned away from the damage and prevents vehicle movement. As shown in **Figure 16-7**, pulling down at point *A* causes an upward force at point *C*. The counterpoint tie-down at point *C* prevents upward movement at *C*.

Pivot-point and counterpoint tie-downs have the same components—blocking and anchoring. ***Blocking*** prevents a change in height or acts as a fulcrum when a change in height is needed. With the exception of an upward pull, the force of any pull will put downward force on the suspension and frame. For example, a forward pull causes the frame to move downward, as well as forward. The blocking shown in **Figure 16-8** prevents the downward movement. ***Anchoring*** is used to prevent forward, rearward, sideways, and upward movement. If the frame will be pulled forward only, there is no need to anchor to prevent sideways or rearward movement.

There are several different methods of making tie-downs. In a ***hook-and-block tie-down***, **Figure 16-9**, a frame hook is inserted into a hole in the frame or at a junction between a cross member and the frame rail. The chain on the hook is tied to the frame machine or the floor. The blocking not only prevents downward movement, but as the pull is applied, the downward force on the blocking keeps the hook in place. If the frame were not blocked and remained on the suspension, pulling in any direction except up would compress the suspension before removing any damage. This

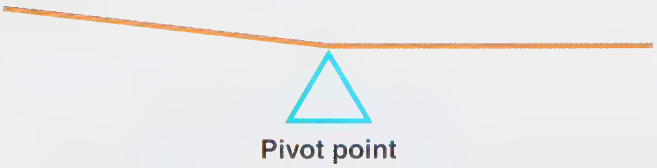


Figure 16-6. *The fulcrum of this lever is called a pivot point in frame straightening.*

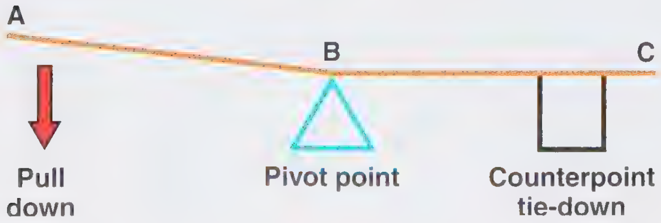


Figure 16-7. *A counterpoint is used to prevent upward movement at C when downward force is applied at A.*

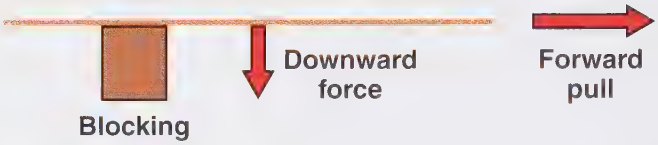


Figure 16-8. *A forward pull causes a downward force on the frame. Blocking prevents movement from this downward force.*

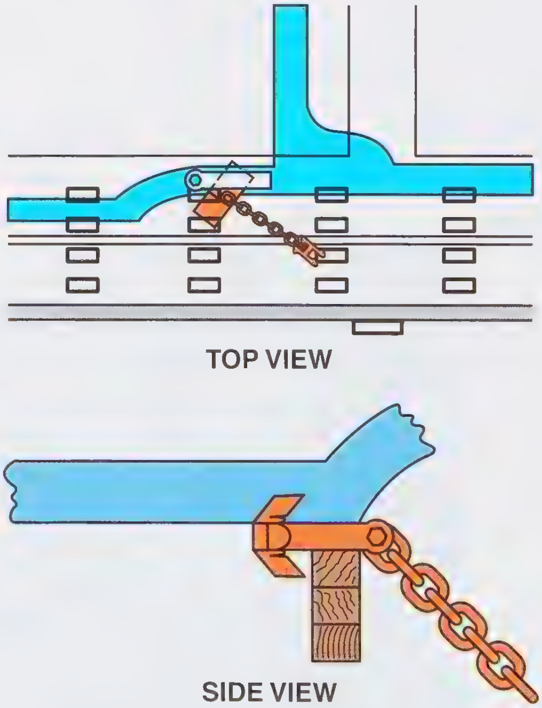


Figure 16-9. *A hook-and-block tie-down can be used to quickly secure a damaged vehicle. (Chief Automotive Systems)*

causes two problems: possible suspension damage and using up the chain travel. Blocking sets the frame at a height where the weight is off the suspension. The suspension does not compress, or load, during the pull.

The ***chain-and-block tie-down***, **Figure 16-10**, is usually made on a frame rail at a cross member. In this example, the looped chain is tied down to the left side and to the rear of the vehicle. If the pull were made at a 45° angle off the right front of the vehicle, this tie-down would oppose the pull. The blocking prevents downward movement.

Full-frame clamps do both anchoring and blocking. **Figure 16-11** shows how these devices are set up on a full-frame vehicle. The location of these clamps is specified in the measuring system setup instructions.

If the center section of the vehicle is not damaged, a tie-down at a cross member is made at each of the four corners of the center section. See **Figure 16-12**. This will hold the vehicle in place and prevent further damage during the pull. If straight-ahead pulls are used to remove the damage, all anchoring can be straight back. See **Figure 16-12A**. In this example, a forward pull is made on the right frame rail. The tie-down closest to the damage acts as a pivot point, holding the undamaged portion of the frame in place so the pull can act on the damage ahead of the tie-down. The other tie-downs are counterpoints, positioned away from the damage to prevent movement of the frame.

If an angle pull or side pull must be made, pivot-point tie-downs are also needed near the damage. When an angle pull or side pull moves a frame, the counterpoint tie-down opposes the movement. The two tie-downs closest to the damage prevent the vehicle from moving in the direction of the pull, and the two counterpoint tie-downs farthest from the damage prevent the vehicle from spinning.

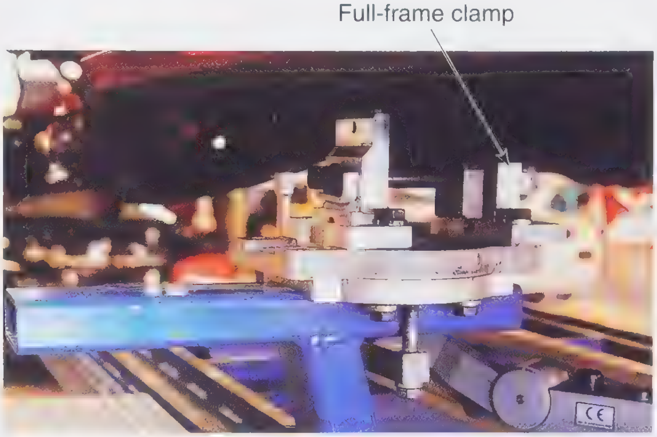


Figure 16-11. *A full-frame clamp is placed at specified locations. This clamp is attached to the lower portion of a box frame.*

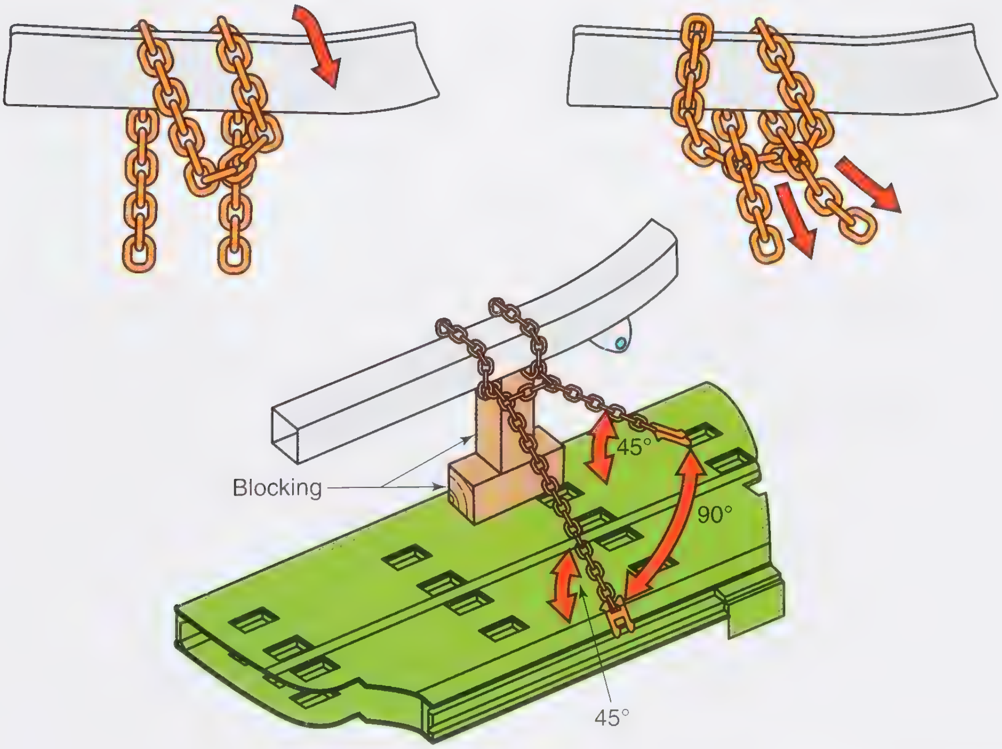


Figure 16-10. *A chain-and-block tie-down should be placed at a cross member if possible. (Chief Automotive Systems)*

A counterpoint tie-down will prevent the frame from spinning about the axis of the pivot tie-down. When an angle pull shown in **Figure 16-12B** is made to the right, pivot tie-downs prevent the frame from moving toward the pull. Without counterpoint tie-downs, the rear of the frame would move to the left. In other words, the frame would spin about the axis of the pivot. With pivot and counterpoint tie-downs, the frame can move only in the damaged area.

The same idea holds true for pulls needed to change height. If a downward pull is needed at the end of a frame

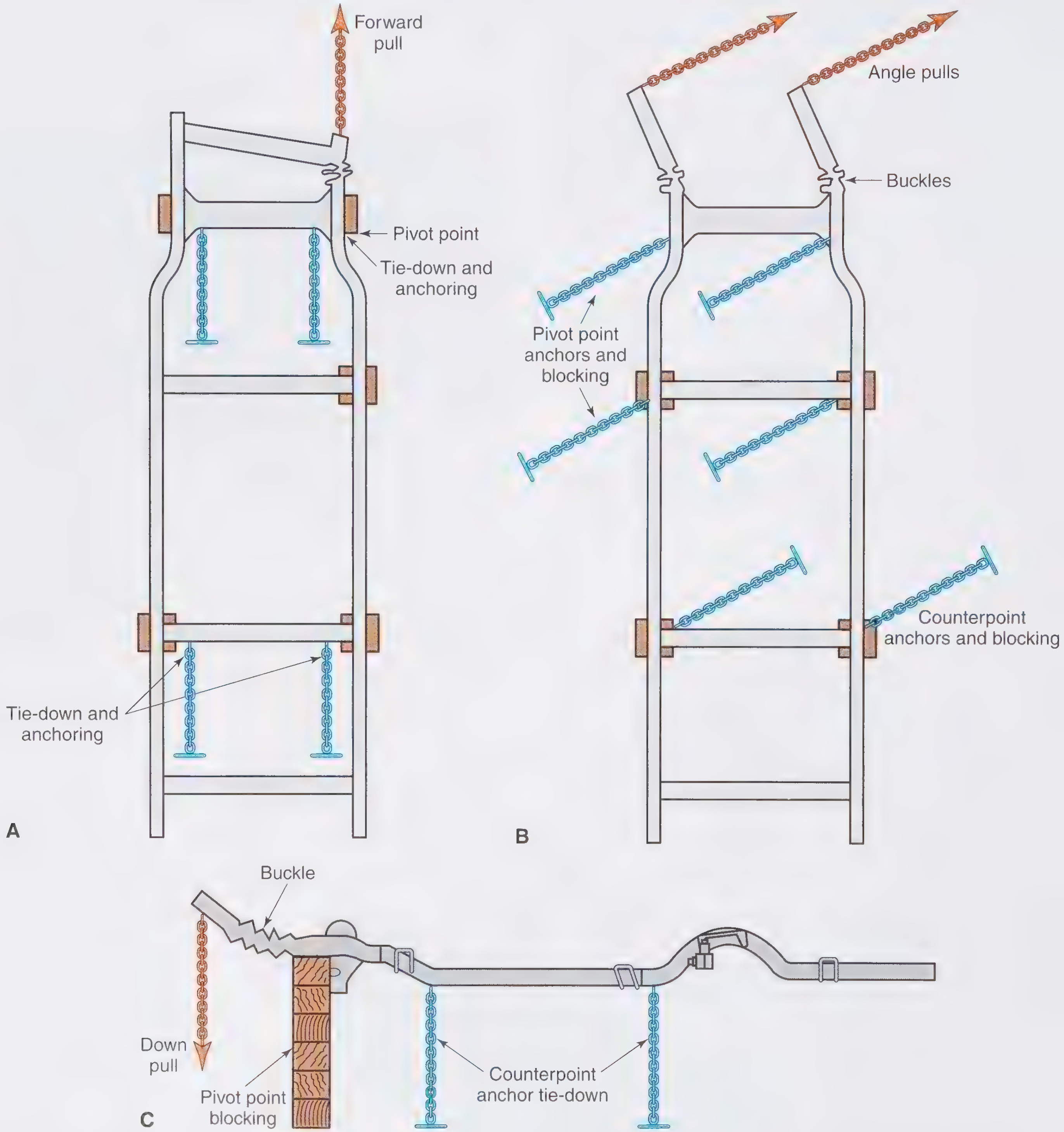

Forward pull
Pivot point
Tie-down and anchoring
Tie-down and anchoring
A
Angle pulls
Buckles
Pivot point anchors and blocking
Counterpoint anchors and blocking
B
Buckle
Down pull
Pivot point blocking
Counterpoint anchor tie-down
C

Figure 16-12. *A—The tie-downs are straight back to oppose the forward pull . B—Two angle pulls are made on this frame. Notice that there are two pairs of pivot points and one pair of counterpoints. C—Pivot point blocking just behind the buckle concentrates the force of the down pull on the buckle. Counterpoint tie-downs prevent upward movement, also concentrating the down pull on the buckle.*

rail, a pivot-point tie-down and blocking are placed just behind the portion of the frame that needs to be moved down. See **Figure 16-12C**. This acts as the fulcrum of a lever. To prevent leverage, a tie-down is made at the rear of the frame to prevent upward movement.

If the center section of the vehicle is damaged, not all four corners can be tied down. Pulls must be made in the center section to correct the damage.

Figure 16-13 shows a bar placed against the frame. As the frame is pulled to the side, the bar acts as a fulcrum and bending takes place at the bar. A chain wrapped around the frame as a pivot-point tie-down could be used in place of a bar.

The anchoring chain of a tie-down should be tight before pulling. If the chain is loose, the pull force will move the vehicle until the slack in the tie-down chain is taken up. Not only does this use up ram or chain travel, but it may also change the angle of the pull if the vehicle moves sideways.

To spread out the force of the pull, each tie-down should be equally tight. If one tie-down is tighter than the other, the pull force will be concentrated on the tighter tie-down. Concentration of the pull force on one tie-down could lead to additional frame damage at that tie-down. To prevent this problem, make each tie-down as tight as possible before the pull. During the pull, monitor the tie-downs to see if one of them becomes slack. If this happens, it means that one of the tie-downs is opposing all the pull force. Another way to avoid this problem is to use a pulley to equalize the pull force between two tie-downs. See **Figure 16-14**. Remember that the tie-downs must be stronger than the pull.

As mentioned previously, tie-downs can also be used to correct damage. **Figure 16-15** shows how this works. The left frame rail is high ahead of the rear suspension arch. When the damage is corrected at the

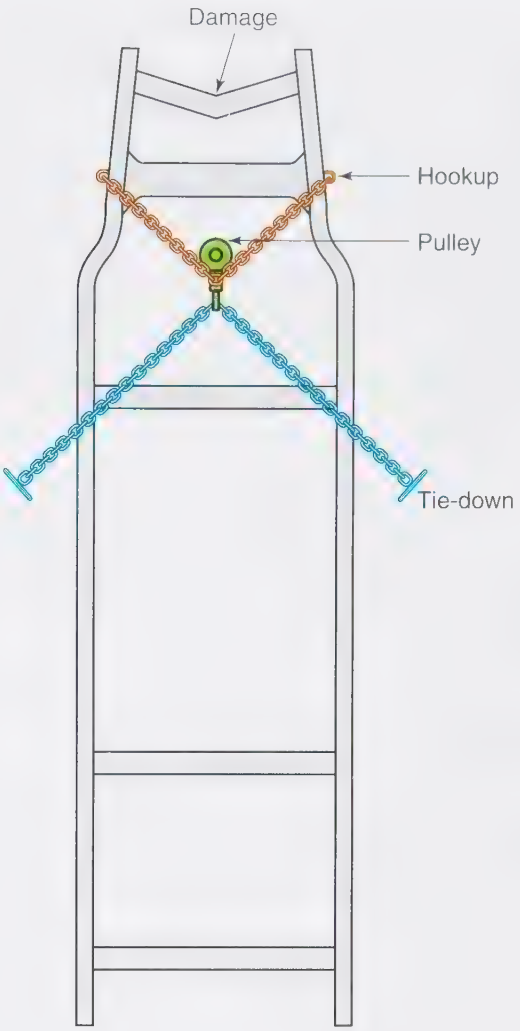


Figure 16-14. *A pulley is tied to the frame machine and to the chains on the frame rails. As the pulls are made, the pulley equalizes the pressure on the chains.*

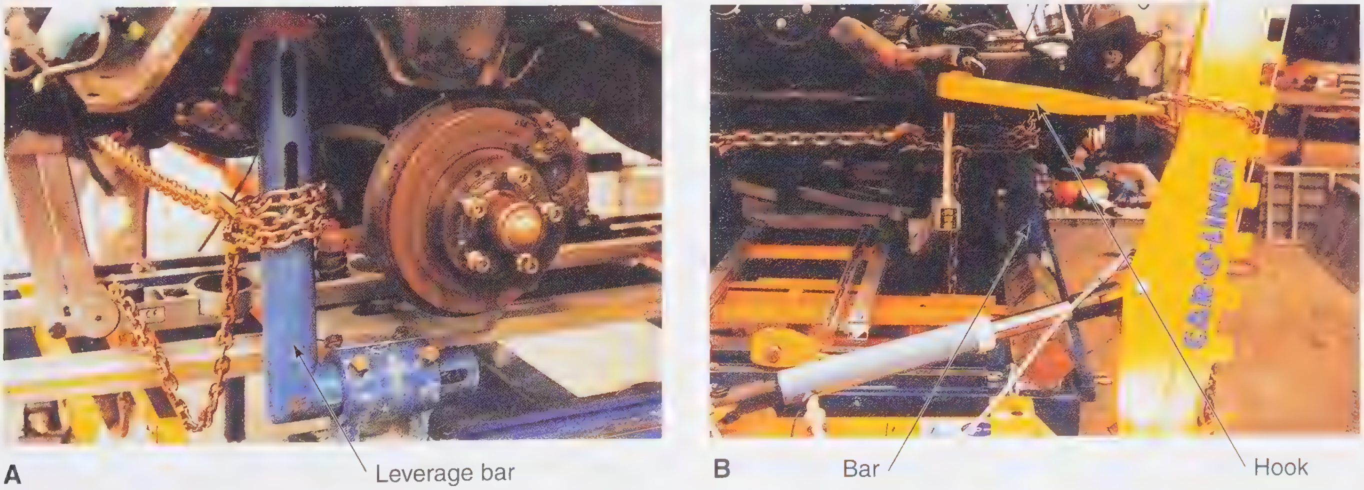


Figure 16-13. *A—The leverage bar is set up against the left frame rail. B—The pull is made on the left frame rail.*

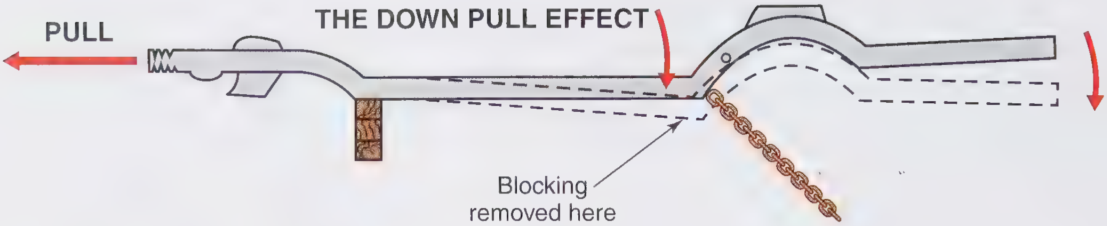


Figure 16-15. *Anchoring without blocking will allow the frame to move down during a forward pull. (Chief Automotive Systems)*

front of the vehicle by forward pulls, a downward force is generated at the rear of the vehicle. This downward force can be used to lower the rail. No blocking is used in the tie-down, only anchoring. Pulling forward on the front lowers the rear. Once the rear has been returned to its proper height, it should be blocked in place to prevent further downward movement.

Hookups

Hookups attach the pull to the frame. Hookups must be stronger than the damage. If they are not, the hookups will give way before the damage moves. There are several different types of hookups used in full-frame repair.

In a ***chain wrap hookup***, **Figure 16-16**, the frame chain is wrapped around the frame rail or cross member. This type of hookup can be used to make straight, angle, upward, downward, or side pulls. Care must be taken when using a chain wrap. As the chain is pulled, the frame or cross member can be crushed.

In a ***chain basket hookup***, the chain is looped around a cross member and tied to itself. See **Figure 16-17**. A pull chain is attached to the chain basket. This type of hookup can be used to pull suspension mounts. It is used to make straight, angled, upward, downward, or side pulls.

Figure 16-18 shows a ***bar hookup*** that is bolted to a frame. The holes in the bar are lined up to existing holes in the frame. This type of hookup can be used to make straight, side, upward, or downward pulls.

A hookup can simply consist of a hook inserted into a frame rail hole. See **Figure 16-19**. The hook can also be placed at a cross member. If the pull is too strong, this type of hookup can damage the frame. The damage shown in **Figure 16-20** was caused by a small hook that concentrated the force of the pull in a small area. Hooks can also be broken by a strong pull. A hook is useful only if the hole is oriented properly for the pull. Straight, angled, upward, downward, and side pulls are possible if an appropriate hole is available.

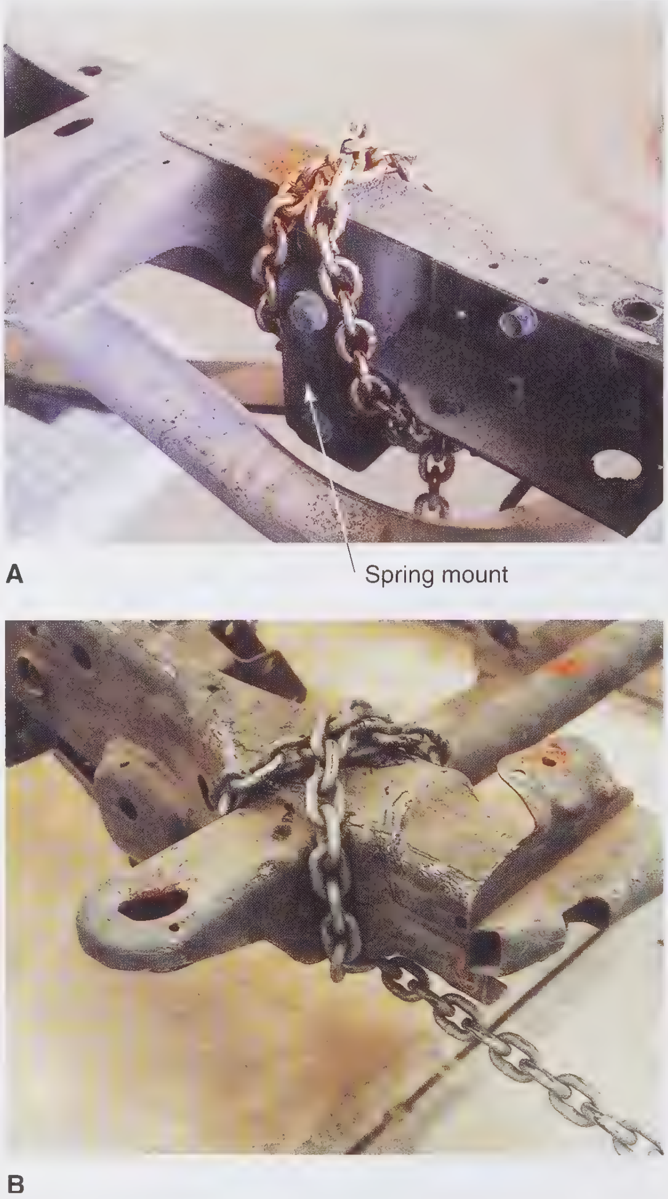


Figure 16-16. *A—This frame wrap is made at a spring mount. The hookup is for a down pull. B—This is a frame wrap for a forward pull. The chain is wrapped around the front cross member and radiator support mount.*

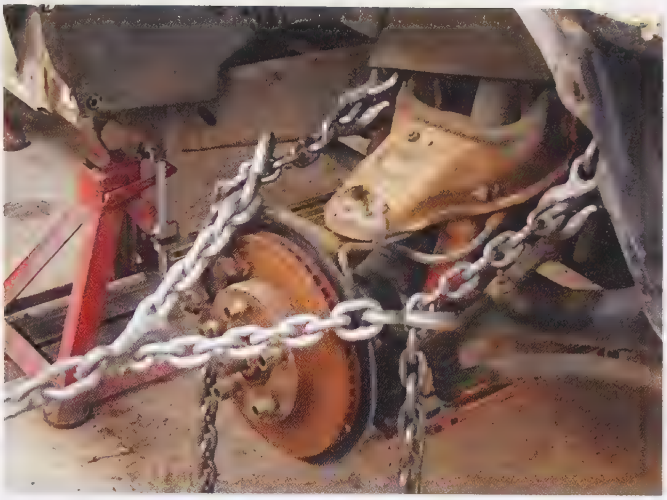


Figure 16-17. *In a basket pull, the chain is wrapped around the frame rail.*

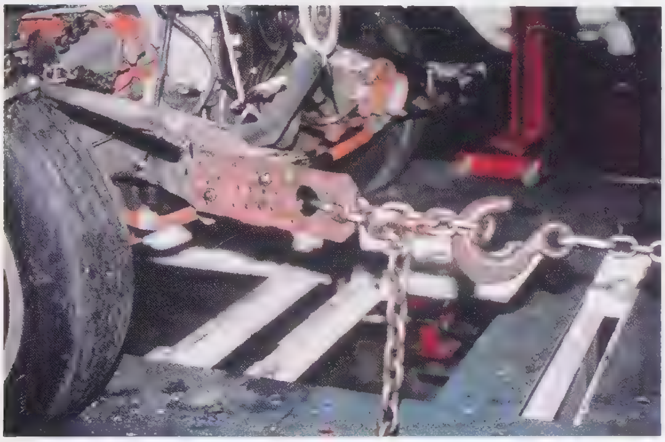


Figure 16-18. *In this example, a bar is bolted to the frame rail to make a pull. (Bee Line)*

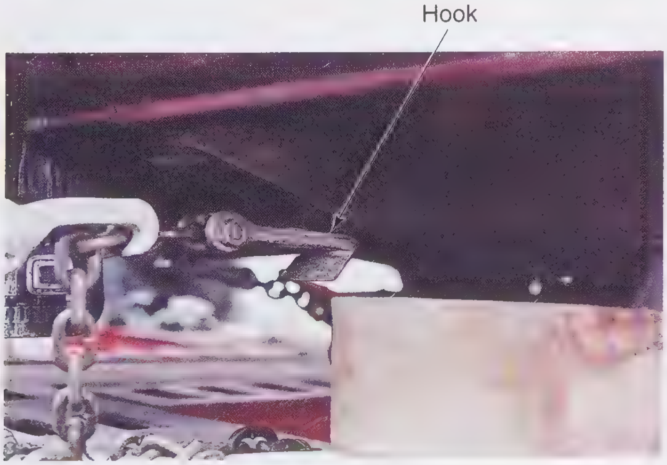


Figure 16-19. *A hook can be used to make a side pull.*

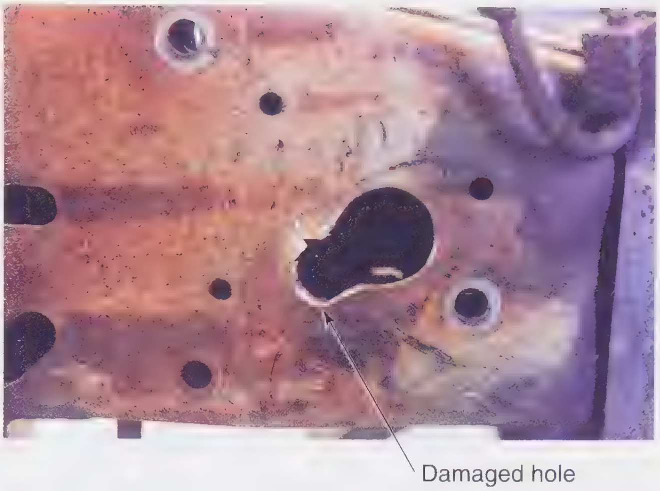


Figure 16-20. *Due to the small contact area, a hook can tear a frame if too much pressure is applied.*

A T-hook inserted into a frame hole is shown in **Figure 16-21**. The T-hook works best in a long, slotted hole. The hook is turned for placement in the slotted hole. As with a standard hook, a T-hook is only useful for straight, angled, upward, downward, or side pulls if a hole is available. A strong pull with this type of tool can also damage the frame or the hook itself.

A slip hook can be used to make a quick hookup to the frame. The slip hook can be inserted into a large hole or used on a flange as shown in **Figure 16-22**. Because the force is concentrated in a small area, there is a risk of damage when using this type of hook. When

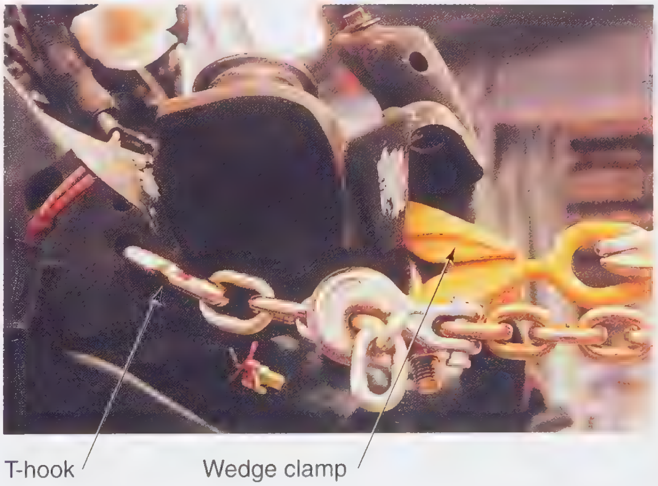


Figure 16-21. *A T-hook is inserted into a frame hole. The T-hook alone could rip out the hole. When the T-hook is used in conjunction with a wedge clamp, damage is less likely.*

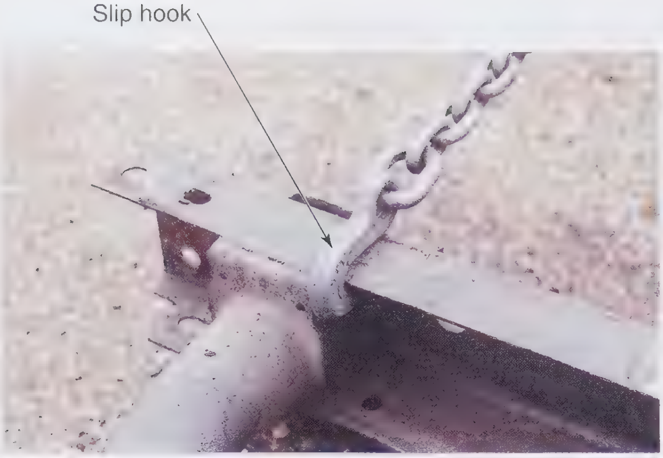


Figure 16-22. *This slip hook is set up to pull a frame flange. Because of the small contact area of the hook, it can easily damage the frame. However, this hookup can be made quickly.*

attached to a flange, a slip hook can be used for side or angled pulls. When placed in a large hole, the slip hook can be used for straight, angled, upward, downward, and side pulls.

An L-hook can make a quick hookup. **Figure 16-23** shows an L-hook in use. It can be placed on a C-channel buckle for a side pull. An L-hook can also be used on a cross member for a straight or angled pull.

A clamp, **Figure 16-24**, can be used to hook up to the end of a frame rail. Some technicians make a MIG weld bead at the end of the rail. This bead keeps the clamp from slipping off the rail. The clamp hookup can be used for straight or angled pulls.

Figure 16-25 shows a plate welded to a full-frame buckle. The plate is attached to the frame with a continuous MIG weld. The plate is welded in the deepest part of the buckle on a box frame. A hole can be cut in the plate for the pull chain or slip hook attachment. The plate can also be grasped with a clamp. The welded-plate hookup can be used for angled or side pulls.

Using a nylon strap is a quick way to grab a frame. See **Figure 16-26**. Like a chain, the strap tends to crush whatever it is wrapped around. Do not exceed the rated capacity of the strap. For forward or angled pulls, wrap the strap around a cross member. For side pulls, wrap the strap around the frame rail at a cross member. The strap can be placed at a cross member or a frame rail for upward or downward pulls.

If the frame has a reinforced hole, a Grade 8 bolt can be inserted through the hole to attach a U-strap to the frame. In the example shown in **Figure 16-27**, the reinforced hole has a tube running through the box frame. The bolt inserted through the tube holds the U-strap in place, and the chain is attached to the U-strap.

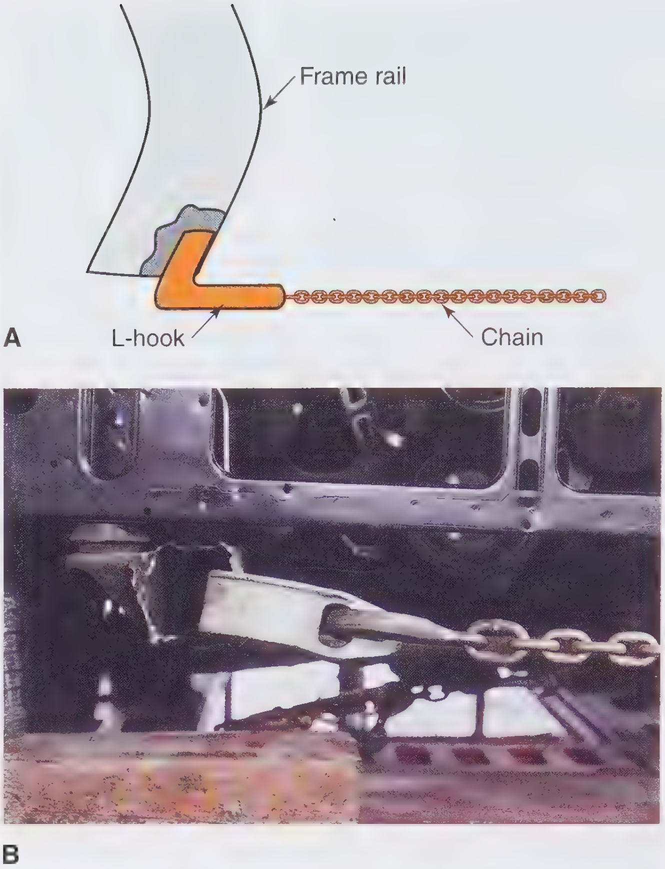


Figure 16-23. *A—A small L-hook is used to pull a frame rail. This type of hook does not have a strong grip on the frame rail. Use this type of hook only for a side pull. B—Never use an L-hook for an angle pull on a frame rail, as it will slip from the rail.*

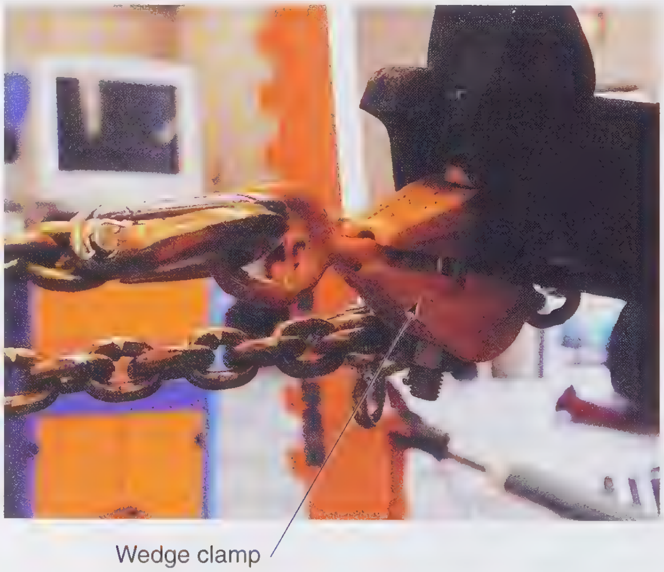


Figure 16-24. *A wedge clamp is placed at the end of a frame rail.*

To prevent damage to the frame, use multiple hookups whenever possible. This will help spread the force of the pull. **Figure 16-28** shows multiple hookups—a clamp and a T-hook—on one pull. The force of the pull is spread out over two areas, decreasing the likelihood of damage.

Chain-wrap tie-downs and hookups share two common problems. When a C-channel frame is wrapped with a chain and force is applied, the frame will tend to collapse, **Figure 16-29**. Positioning the tie-down or hookup at a cross member may help if the cross member

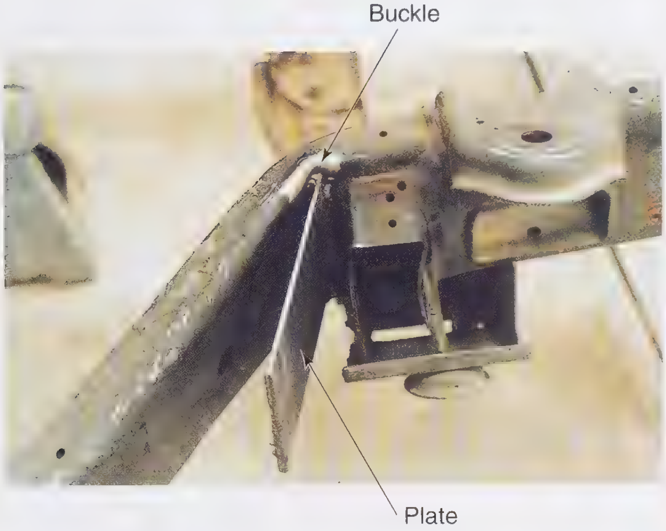


Figure 16-25. *This plate has been welded on a frame buckle. As the frame rail is pulled forward, a side pull is made on the plate and the buckle.*

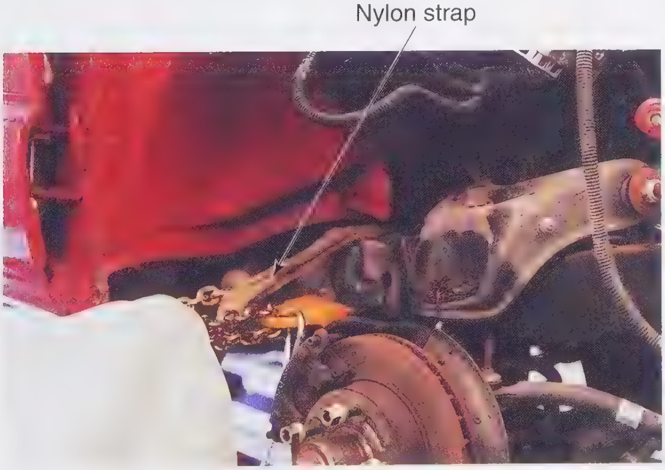


Figure 16-26. *A nylon strap is wrapped around the frame. This is a boxed area of the frame, so collapsing the frame rail is not a concern.*

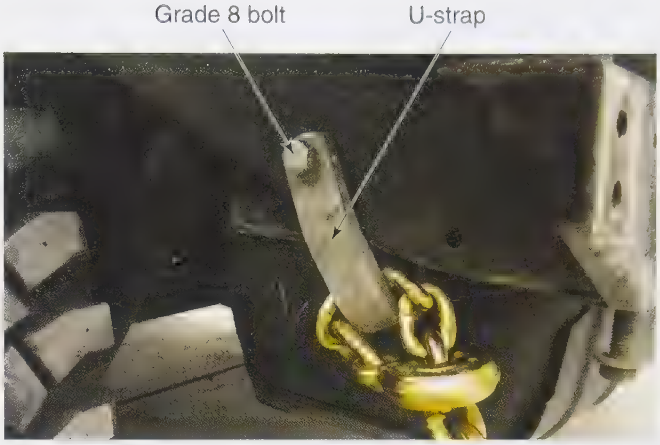


Figure 16-27. *A U-strap can be attached to a reinforced hole in the frame with a Grade 8 bolt.*

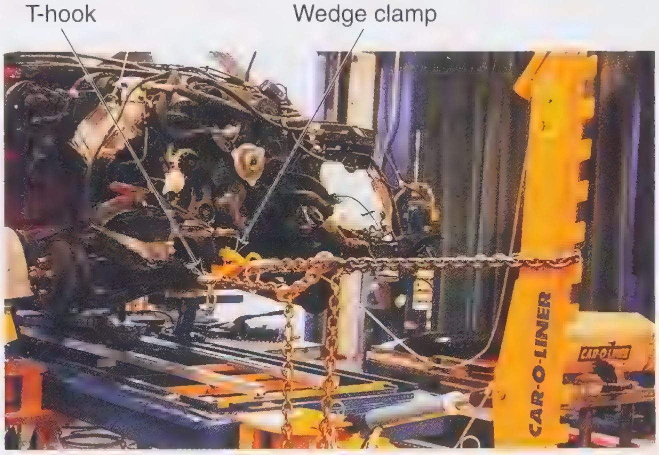


Figure 16-28. *There are two hookups used to repair the damage to this vehicle, a T-hook and a wedge clamp.*

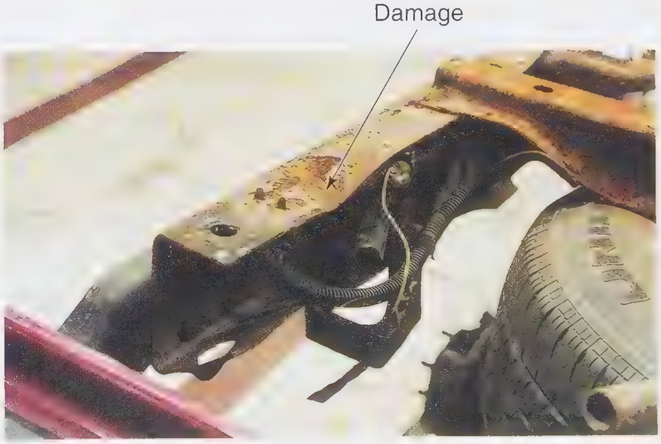


Figure 16-29. *These frame flanges have been pushed together by a chain wrap.*

extends the full height of the frame rail. Unfortunately, there may be only one cross member of this type on the vehicle. Another way to prevent collapse in a tie-down is shown in **Figure 16-30**. In this example, a piece of steel has been cut and wedged into the C-channel. This will support the flanges of the frame and prevent collapse. This procedure works, but it is tedious and time-consuming. When making a chain hookup to pull against the flanges, a piece of steel stock cut slightly taller than the frame can be positioned as shown in **Figure 16-31**. In this case, the tightening of the chain takes place on the steel stock and not the frame rail.

In addition to frame rail flange collapse, chain-wrap tie-downs and hookups may also present clearance problems. The 3/8" chain used in frame repair may be difficult to thread between the frame and the vehicle's body or other obstructions. These obstructions include the gas tank, suspension mounts, and mechanical parts. To get around this problem, a 1/4" frame chain can be used. This smaller chain should be double-wrapped to provide enough strength for a 10-ton pull. If a 1/4" frame chain is not available, obstructing parts can be loosened and moved slightly for additional clearance.

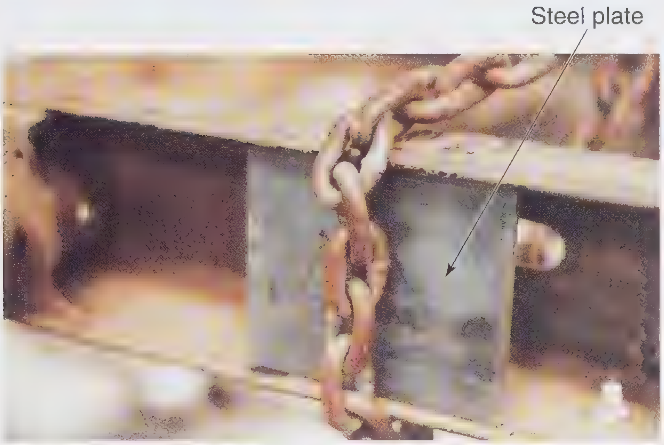


Figure 16-30. *A piece of steel stock prevents collapse when wrapping the frame.*

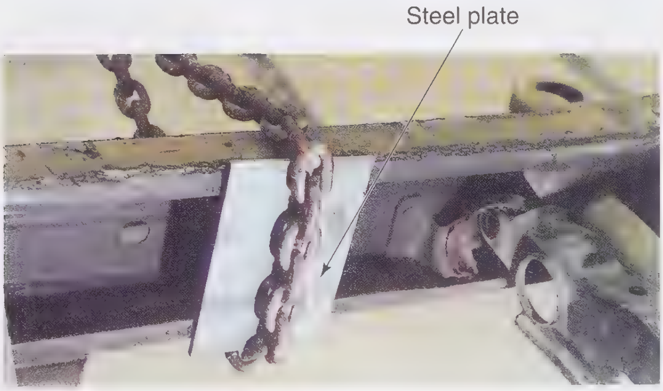


Figure 16-31. *Pulling against steel stock prevents frame flange damage.*

Pulls

Pulls are used to move a damaged frame to its correct location. The direction of the pulls and the number of pulls are important. Pulls are made in the following directions:

- Forward pull—The forward pull is level with the floor and parallel to the frame rails. It is used to restore length. See **Figure 16-32**.
- Angle pull—An angle pull, **Figure 16-33**, is level with the floor and not parallel or perpendicular to the frame rails. This type of pull is used to restore length and width.
- Side pull—The side pull is level with the floor and perpendicular to the frame rails. This type of pull is used to restore width. **Figure 16-34** shows a side pull.
- Upward pull—The upward pull is made perpendicular to the frame. Upward movement can also be made with a push. A ram placed under the frame can be used to push up on the frame rail. An upward pull or push corrects sag.
- Downward pull—As its name implies, the downward pull, **Figure 16-35**, is perpendicular to the frame and is used to restore height while correcting kickup.
- Double-stretch pull—The double-stretch pull is actually two pulls in opposite directions. It is used to restore length. **Figure 16-36** shows a double-stretch pull.

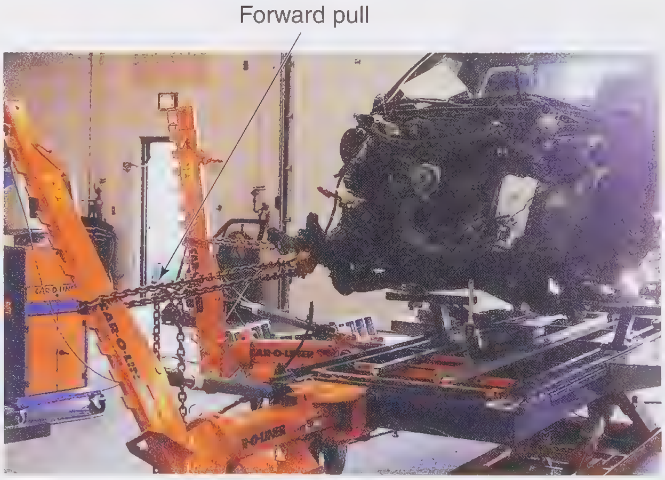


Figure 16-32. *The tower on the left is making a forward pull on the right frame rail.*

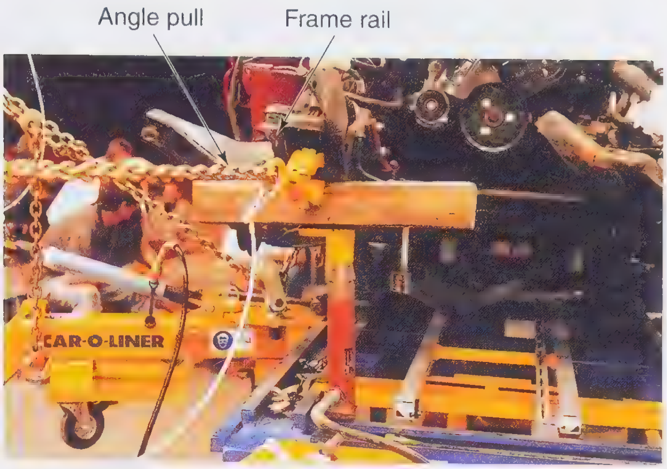


Figure 16-33. *The tower has been positioned to make an angle pull, moving the frame rail out and forward.*

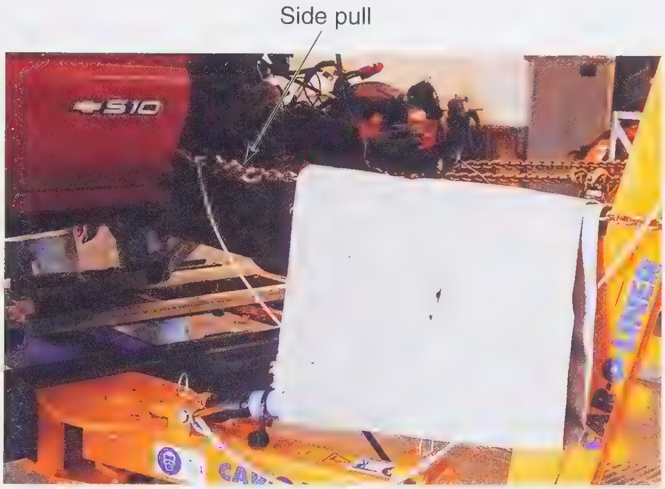


Figure 16-34. *This side pull is made on a buckle in the frame. The pull is perpendicular to the frame rails.*

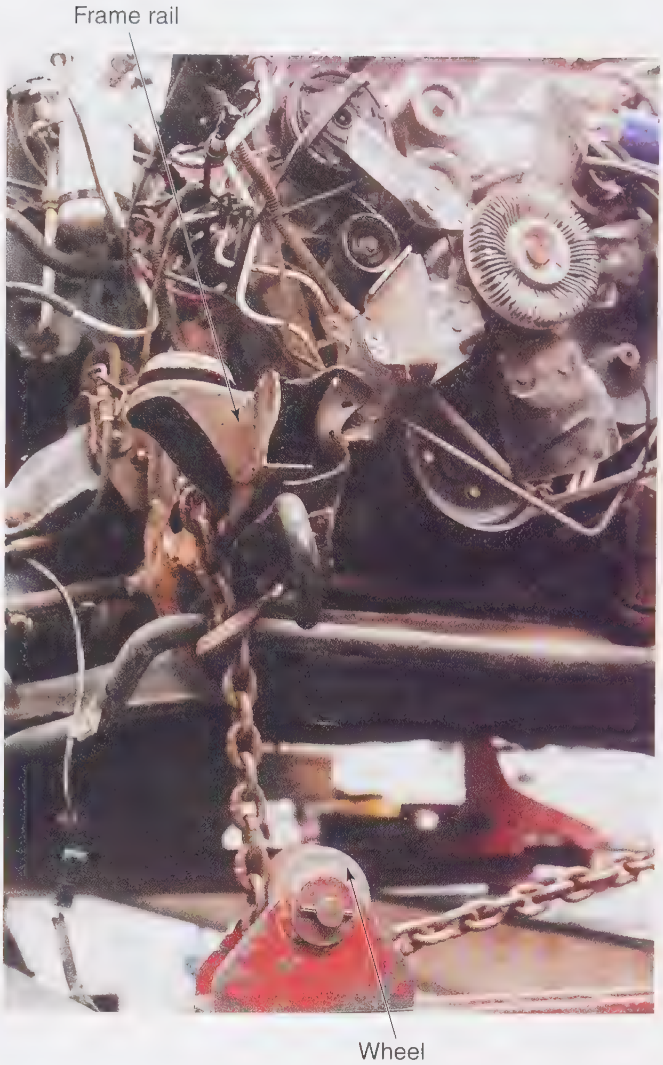


Figure 16-35. *This is a down pull on a right frame rail.*

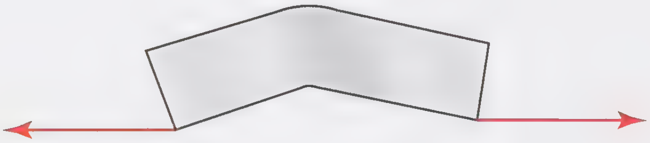


Figure 16-36. *This is a double-stretch pull. The pulls are made in opposite directions to straighten the bend.*

Combination pull—A combination pull attempts to restore length, width (centerline), and height in a single pull. This type of pull can work if the damage is confined to a small area. For example, a frame rail damaged ahead of the front suspension mounts is considered a small area. If a larger area is damaged, such as a front hit that causes damage to extend to the area behind the front suspension mounts, individual pulls must be made to restore the length, width, and height.

Several pulls working together are called ***multiple pulls***. **Figure 16-37** shows an example of a multiple pull setup in which the frame rail is being moved in two different directions. In this case, one frame machine tower is set up to make a side pull while the other is set to make a down pull. When you must make two pulls in different directions, make one pull at a time rather than making both pulls at the same time. Simultaneous pulls in different directions tend to get in each other's way. Simultaneous multiple pulls in the same direction will spread the pull force over a large area, lessening the chance of damage to an area.

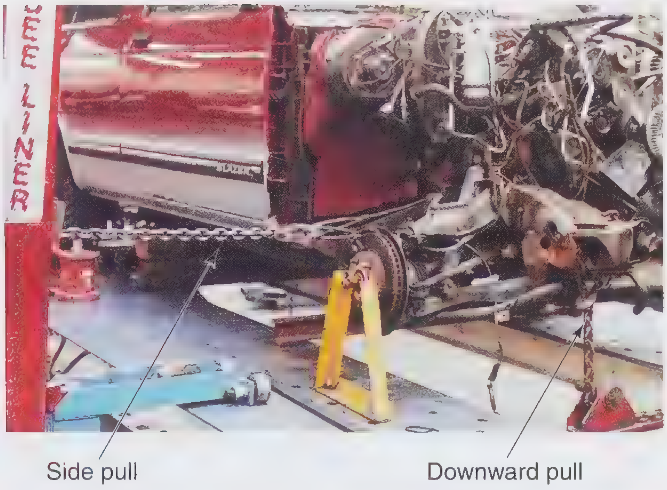


Figure 16-37. *One pull moves the frame rail to the right and the other moves the rail down. These are multiple pulls.*

Let's look at an example of pull direction. **Figure 16-38** shows a square that has been damaged by an impact force at *C*. To correct the damage, line *A-B* needs to move to the right and line *C-D* needs to move forward and to the right. **Figure 16-39** shows one solution to this problem. Two pulls are made—a forward pull and a side pull. Notice that the angle between the pulls is 90°. The desired position of line *C-D* is indicated by the dotted line. If the hookup is made at *C* and the pull is based on a straight line from the straightened condition, the pull will bring *C-D* forward. Another pull can be made to take *A-B*, *B-C*, and *C-D* to the right. Assuming there is a buckle at *D*, the forward pull will begin to unlock the buckle and the side pull will continue to unlock the buckle. An additional forward pull on *C* will help remove the buckle and restore the length of line *C-D*.

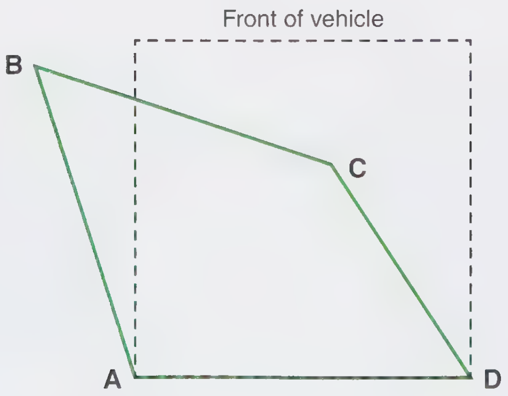


Figure 16-38. *The impact on this box caused sidesway and mash.*

With multiple-pull capability, these pulls could be set up to make one pull and then the other pull. With single-pull capability, one pull could be made and then the equipment moved to make the second pull.

Another way to correct this damage is shown in **Figure 16-40**. This is an angle pull that is a combination of the forward and side pulls. Notice that the angle pull splits the 90° angle of the forward and side pulls. This angle pull can be adjusted if one line, such as line *B-C*, returns to its proper position before the others. When determining pull direction, remember that an angle pull can take the place of a forward pull and a side pull.

Deciding on the pull direction and number of pulls is the most critical part of frame repair. The technician

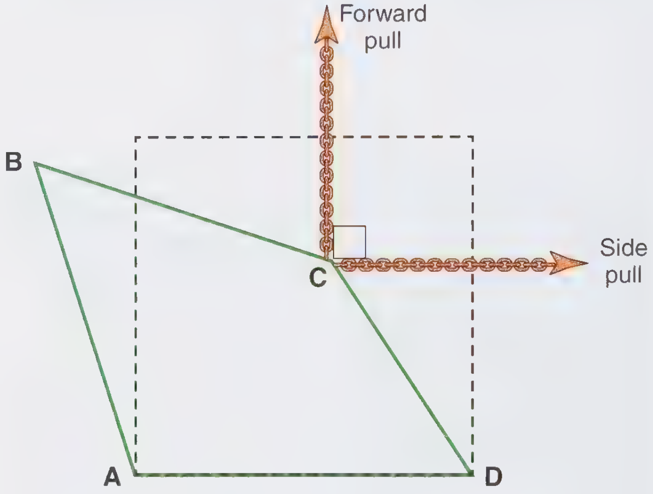


Figure 16-39. *The forward pull is intended to straighten C-D, while the side pull is intended to square up the box.*

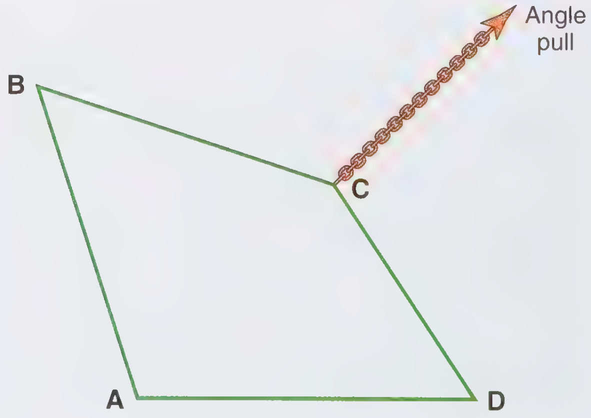


Figure 16-40. *This angle pull is intended to straighten the box with one pull. The angle will need to be changed as the pull progresses.*

must take into account the capabilities of the available frame repair equipment. A frame machine that has only one tower can make only one pull at a time. A multiple-pull tower can make two or more pulls simultaneously. Multiple pulls in the same general direction spread out the force of the pulls. As in unibody repair, multiple pulls in the same direction are preferred to single pulls. By spreading the pull force, there is less chance of damage to the frame. Additionally, less pressure is required from each individual pull. **Figure 16-41** shows multiple pulls on a full-frame vehicle.

When the pull is made, watch the tie-downs, the vehicle, and the damage for movement. The damage is where the movement should take place, but the tie-downs and the vehicle will move until the tie-downs become tight. Something must move during the pull. If something does not move, stop pulling. If there is no movement during the pull, the hookup, tie-down or frame will break.

Pushes

Pushing with a hydraulic ram can correct sag or sidesway. A push with a hydraulic ram can form a pivot point. If a down pull is needed to correct a buckle, the ram can be positioned at the buckle to concentrate the pull on the buckle. The hydraulic ram can be based against any structure that is stronger than the damage or the pull, such as the floor or the bed of the frame machine. A hydraulic ram based against a surface that is weaker than the damage or pull will bend the surface. If the frame machine has towers, the hydraulic ram can be based on the tower for a push on the frame.

Stress Relief

Stress results when a vehicle's frame absorbs collision energy. This stress is a rearrangement of the steel's grain structure. Stress is concentrated in the stronger parts of the frame, such as the corners, flanges, angles, rivets, and buckles. To properly repair a full-frame vehicle, the steel's grain structure must be returned to the original undamaged state. This process is called ***stress relief***. Stress relief is performed when the vehicle is under pulling tension. The tension pulls the metal the desired direction. Stress relief gives the steel grains the energy to rearrange themselves back into their original configuration. Stress relief is just as important in full-frame repair as it is in unibody repair.

Vibration

When using vibration for stress relief, always have the full frame under tension.

WARNING

Never stand directly behind or straddle frame chains while the vehicle is under tension.

Use a short-handled sledgehammer to provide the vibration. A body hammer is too light to provide the necessary force. Hammer on the flanges, angles, and corners of the frame. Hammering on the flanges, corners, and angles will vibrate the steel grains to help them realign under tension. See **Figure 16-42**. Also, hammer on the rivets that hold the cross members and spring mounts to the frame.

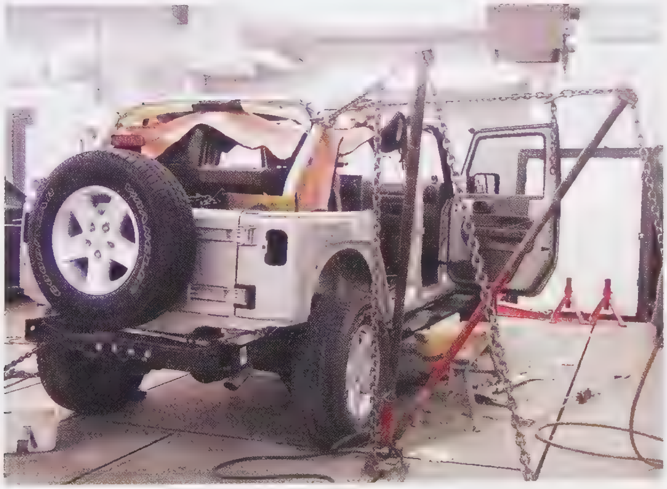


Figure 16-41. *Multiple pulls are applied to straighten the safety cage of this SUV.*

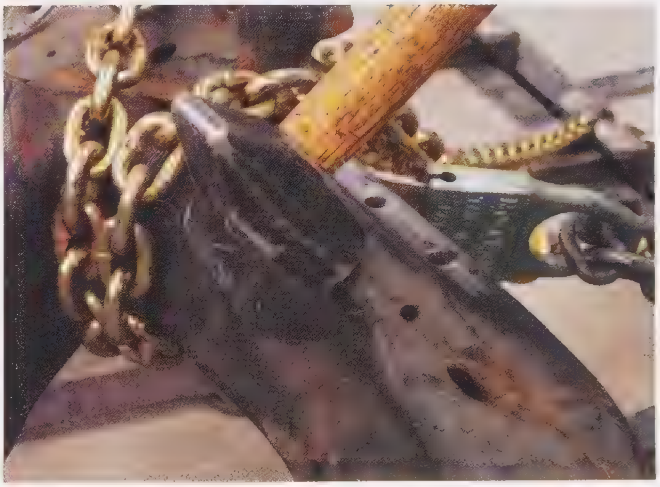


Figure 16-42. *Stress relieve frames by hammering on the corners and flanges. Buckles should be hammered under tension as the pull straightens the buckle.*

If a buckle is present, release the buckle first, then hammer on the flanges at least 2' on either side of the former buckle. Loosen any bolted structures or parts while the vehicle is under tension and tighten after the stress has been released. These structures or parts include the cross members, steering gearbox, radiator support, cab, and pickup truck box.

Heating

Mild steel frames can be heated as part of the stress relief process. Heat causes the steel grains to move about even more than vibration, allowing more effective stress relief. High-strength steel frames should be heated only if recommended by the manufacturer. In either case, follow the manufacturer's recommendations for the maximum temperature and time.

For safety, remove any flammable materials from the heat zone. Gas lines, brake lines, electrical wires, undercoating, fender liners, and rubber bushings should all be removed before heating. Use wax-and-grease remover to dissolve the rust preventive layer from the portion of the frame that will be heated. The rust preventive layer is a waxy coating on the frame. Heat will cause the layer to melt and burn. See **Figure 16-43**.

Apply the corrective force to the frame before heating. This tension gives the steel grains a direction to move toward. Use a rosebud tip on the torch for a large flame, and set the torch for a slightly carburizing flame. Heat an area six to eight times larger than the buckle. Heat the frame corners or buckles only. See **Figure 16-44**.

Gradually raise the temperature of the entire heated area. Do not heat one part to the maximum temperature while the rest of the area is not heated. Use temperature-indicating crayons or an infrared thermometer to monitor the temperature.

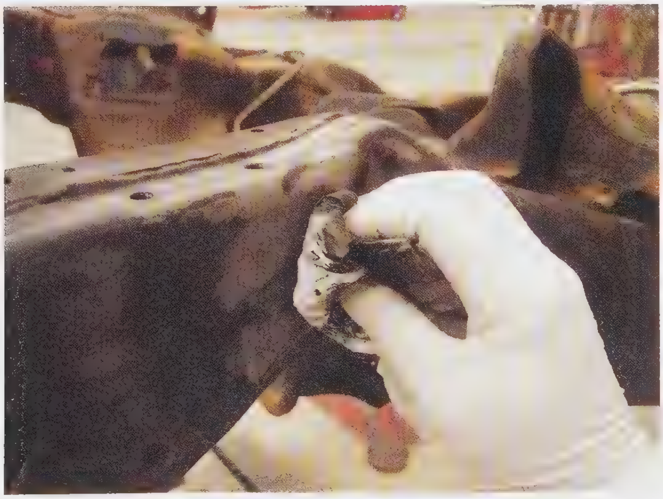


Figure 16-43. *Use wax-and-grease remover to dissolve rustproofing material on frame rails before welding or heating.*

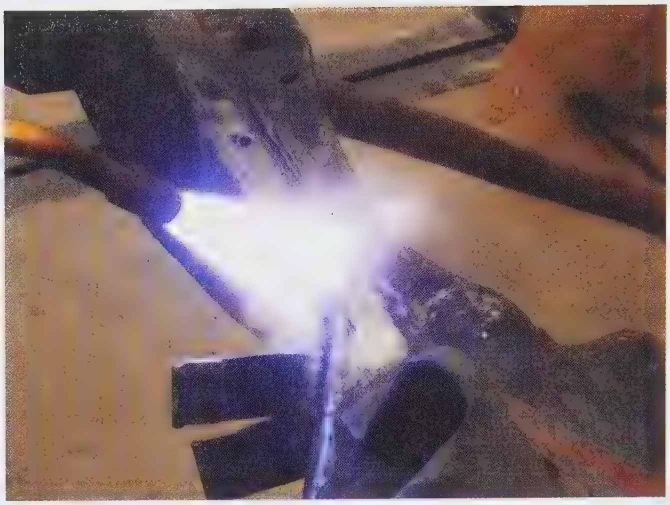


Figure 16-44. *Gradually heat the frame corners or buckles while the frame is under tension.*

WARNING

Always be alert for fires when heating a frame. Keep a blowgun or fire extinguisher nearby when heating to extinguish any fires that may occur.

After heating, allow the frame to cool down naturally. Never speed cooling by applying water or compressed air to the frame. Improper cooling may make the steel brittle.

As previously mentioned, proper stress relief will allow the steel grains to move back into their original positions. This procedure minimizes spring back. ***Spring back (settle back)*** is the tendency of the frame to return to its damaged state once tension is released. This occurs when the grain misalignment is not corrected by the pull. However, if the metal grains are stress relieved while the tension is on the frame, they will orient themselves into a straightened condition. Once the tension is released, the grains will not spring back.

Repairing Specific Types of Frame Damage

Various combinations of tie-downs, hookups, and pulls are used to repair different types of full-frame damage. Because all full-frame parts—side rails, cross members, and suspension mounts—are connected, more than one type of damage is generally present.

If the center section of the vehicle is damaged, it is usually repaired first. The reason for this is that end section misalignment can be caused by center section damage. Once the center section is repaired, the end sections will often return to proper alignment. If an end section is still misaligned after the center section is straightened, the center section can be tied down and the end section can be repaired. The sequence for full-frame repair is similar to that for unibody repair. Begin by straightening the center section of the vehicle.

The length of a frame rail must be restored first. Buckles that make the rail shorter must be released. To release the buckles, put tension on the rail. Then release the buckle. If more than one buckle is present, start with the buckle farthest from the direct damage. Once the length of the rail is restored, evaluate the centerline and height misalignment. If the centerline misalignment is greater than the height misalignment, pull the centerline next.

Finally, once the centerline is correct, make pulls to set height. Centerline and height correction may also involve releasing buckles. ***Overpulling*** may be needed to compensate for spring back. Overpulling involves pulling a damaged frame rail slightly past its proper location. Spring back can be minimized by stress relieving while the frame is under tension.

Repairing Buckles

As in sheet metal repair, buckles must be released before the frame can be straightened. This section gives some examples of common buckle types and explains how to repair them.

If both rails are damaged, it may be easier to pull one rail at a time. If the front cross member can be unbolted and the damage is in front of the engine cross member, the rails can be pulled separately. Pulling each rail separately allows the technician to concentrate all the equipment on one rail. A front impact on one box frame rail often causes a buckle to the rear of the engine cross member where the frame widens.

A side impact at the front of the vehicle may cause buckles in both box frame rails, ahead of the engine cross member. Both rails will have buckles, but the buckle in the nonimpact rail will be more severe.

In **Figure 16-45,** an impact caused a buckle behind the front suspension mount. The buckle is not accessible from the back because of the boxed construction of the frame. To repair this damage, a pull plate is welded to the deepest part of the buckle. The frame is tied down to oppose the pulls and prevent spinning. See **Figure 16-46**. Two types of pulls are made: forward and side. The forward pulls are hooked up to the front

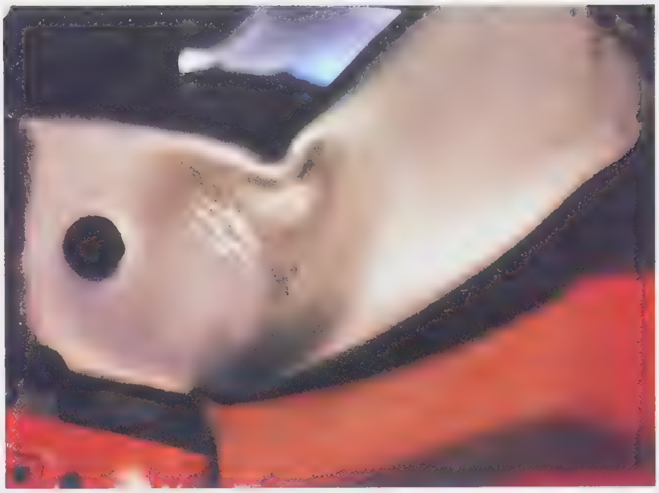


Figure 16-45. *An impact on the front of the box rail caused a buckle behind the front suspension mount.*

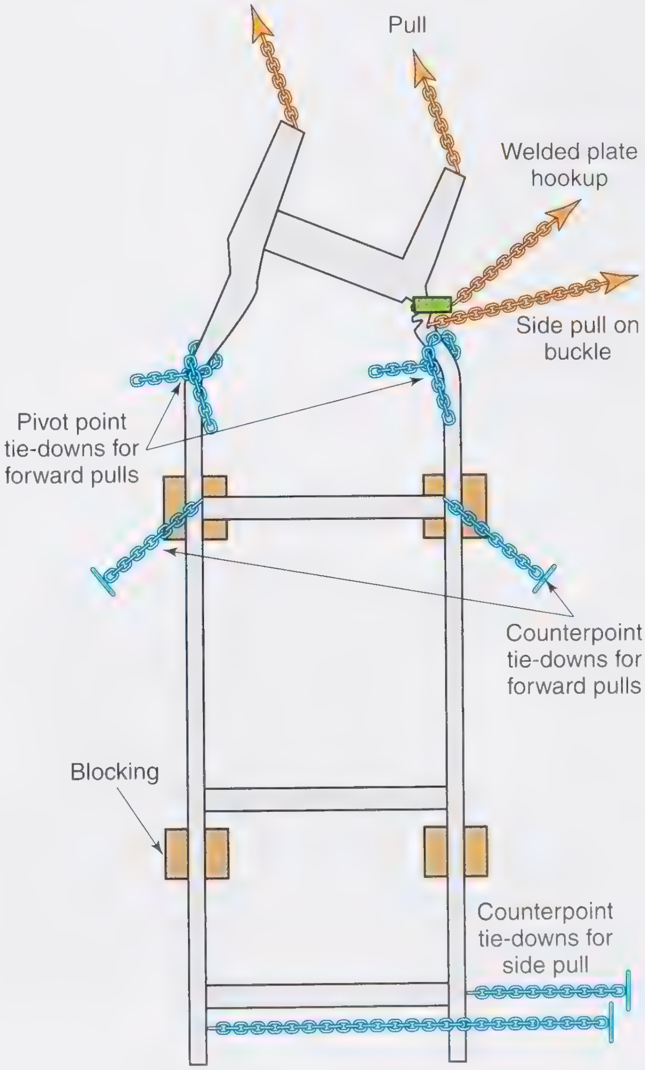

Pull
Welded plate hookup
Side pull on buckle
Pivot point tie-downs for forward pulls
Counterpoint tie-downs for forward pulls
Blocking
Counterpoint tie-downs for side pull

Figure 16-46. *Forward pulls and a side pull will remove the buckle from this frame rail.*

of the frame rails, and the side pull is hooked up to a welded-on plate. Both pulls will help unlock the buckle. The forward pulls are made first, and the pull on the right rail starts to unlock the buckle by lengthening the rail. Make the side pull next. The side pull causes the low area of the buckle to rise. The frame corners and the buckle should be hammered while under tension to stress relieve the frame. Alternate forward and side pulls to gradually raise the low part of the buckle, and use hammering to lower the high part of the buckle. Do not hammer on the high part until it has moved down and is almost flat. Hammering on the high part of the buckle too soon will cause additional damage by folding the buckle.

The damage shown in **Figure 16-47** was caused by a side impact on the right box rail. The impact caused a buckle in the left frame rail, ahead of the cross member. **Figure 16-48** shows the setup to remove the buckle on the nonimpact frame rail. The removal of the nonimpact rail buckle requires the same type of weld-on plate and side pull. This full-frame vehicle was hit on the front bumper from the side. The front cross member carried the impact force to the nonimpact rail and caused it to buckle. An angle pull will correct the impact rail, while a forward pull straightens the nonimpact rail. A side pull, hooked up to a plate welded to the lowest part of the buckle, will help unlock the buckle. Pivot points, counterpoints, and blocking are set up to immobilize the frame. The angle pull is made first to start the rails moving in the right direction. The forward pull, which is hooked up to the buckle side of the nonimpact rail, follows after the angle pull. The forward pull starts to unlock the buckle. The side pull then raises the low part of the buckle. Stress relieve the frame at this time and then continue alternating angle, forward, and side pulls with hammering to release the buckle.

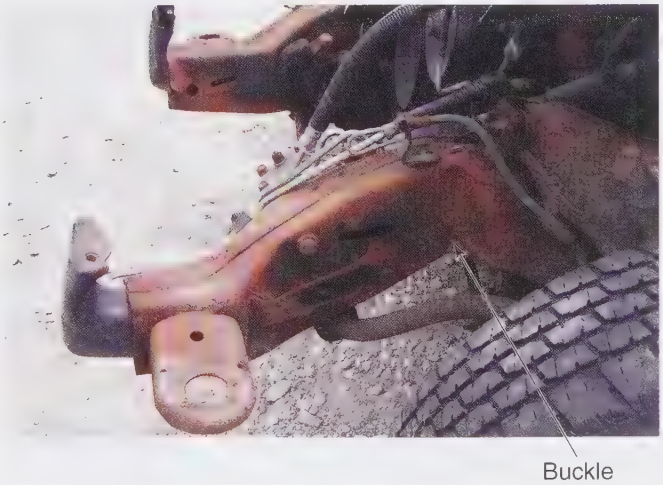


Figure 16-47. *A side impact on the right box rail caused this buckle in the left frame rail, ahead of the cross member.*

If the vehicle manufacturer allows heating and welding on the frame, another way to repair a buckle in a box frame is to cut a window for access to the back side of the buckle. A cut-off tool is used to cut out a 2" square from the box frame opposite the buckle. With the frame under tension, the buckle can be worked from the back side with a hammer or a torch. After the repairs are complete, the piece cut from the frame can be MIG welded back in place.

Two types of buckles that may be found together on a C-channel frame are shown in **Figure 16-49**. The flanges of the C-channel frame face inward. A side impact

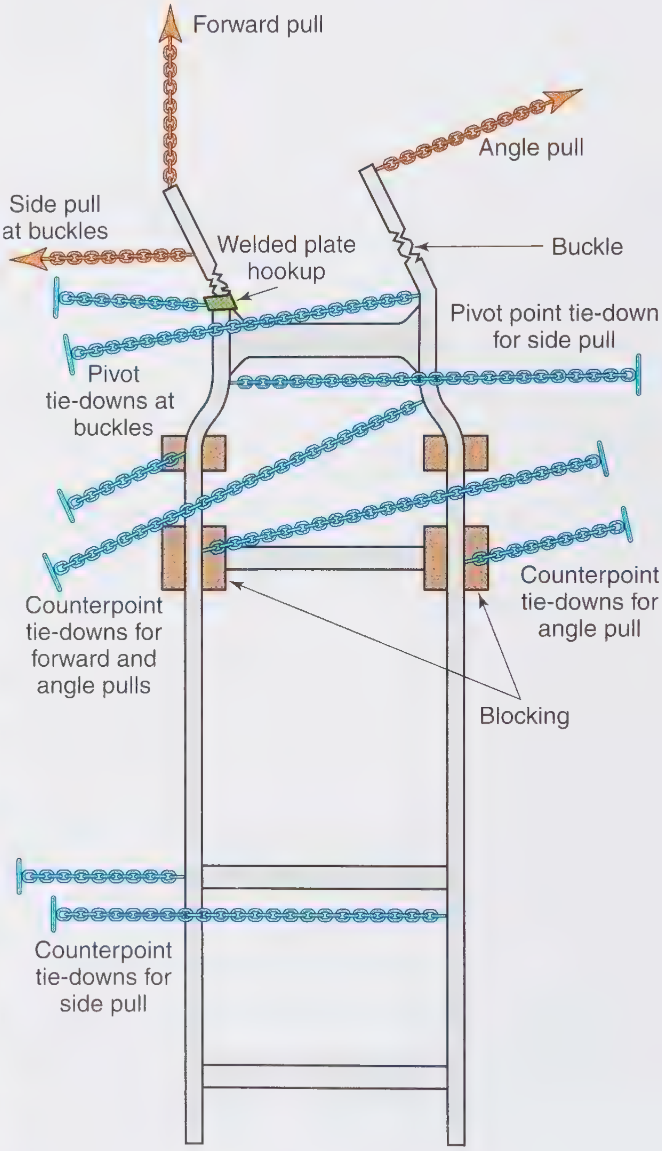

Forward pull
Angle pull
Side pull at buckles
Welded plate hookup
Buckle
Pivot point tie-down for side pull
Pivot tie-downs at buckles
Counterpoint tie-downs for angle pull
Counterpoint tie-downs for forward and angle pulls
Blocking
Counterpoint tie-downs for side pull

Figure 16-48. *Forward, angle, and side pulls will remove the buckle from the nonimpact frame rail.*

causes the flanges on the impact side to compress at a pivot point. This makes a buckle with high arches in the flanges on the impact side. See **Figure 16-49A**. Instead of being compressed, flanges on the nonimpact side are stretched, possibly to the point of tearing. See **Figure 16-49B**. To repair the compressed buckles, the frame is tied down to prevent side movement.

These buckles are repaired using alternating side and forward pulls. The undamaged portion of the frame is tied down with anchoring and blocking. See **Figure 16-50**. The following instructions are for a C-channel frame that has so much sidesway that the nonimpact side has stretched to the point of breaking. If the front cross member is bolted in place or has been damaged and must be replaced, remove it. This will allow the rails to be moved independently. There is quite a bit of work to do in a limited time, and it is twice as much work if you have to work two rails at once. Make the impact rail side pull first. This will start to lower the buckles on the impact rail. If the manufacturer allows heating, pull until the buckles start to move. Then heat the buckles and pull more. Stress relieve the frame with heat or hammering under tension. When the buckle has lowered, make the forward pull and hammer on the remaining buckle to lower it to the proper level.

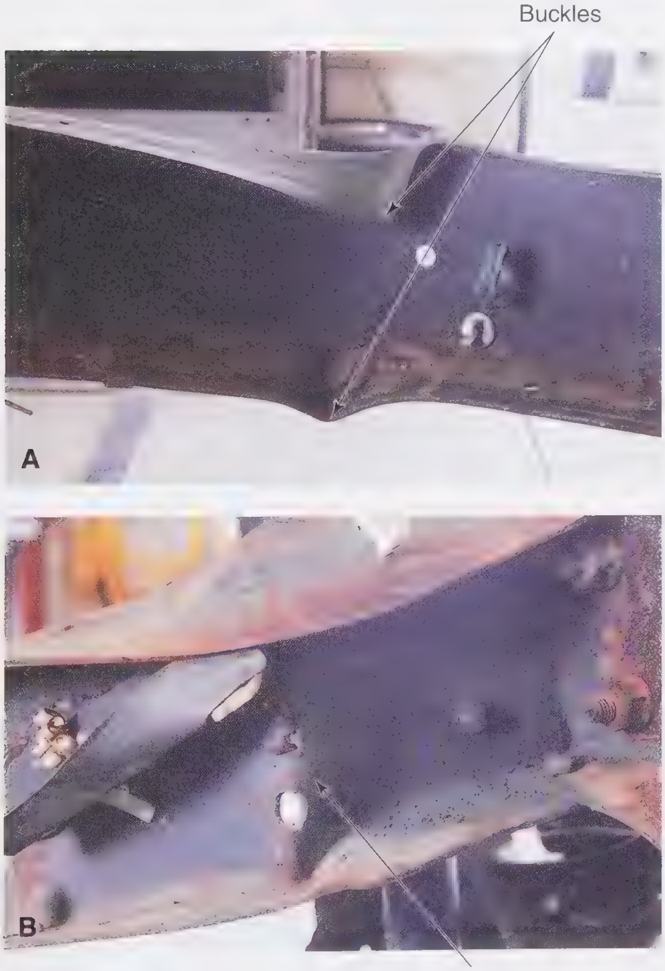

Buckles
A
B
Stretch

Figure 16-49. *A—A side impact on a C-channel frame makes buckles in the impact rail. B—A side impact on a C-channel frame stretches the nonimpact rail.*

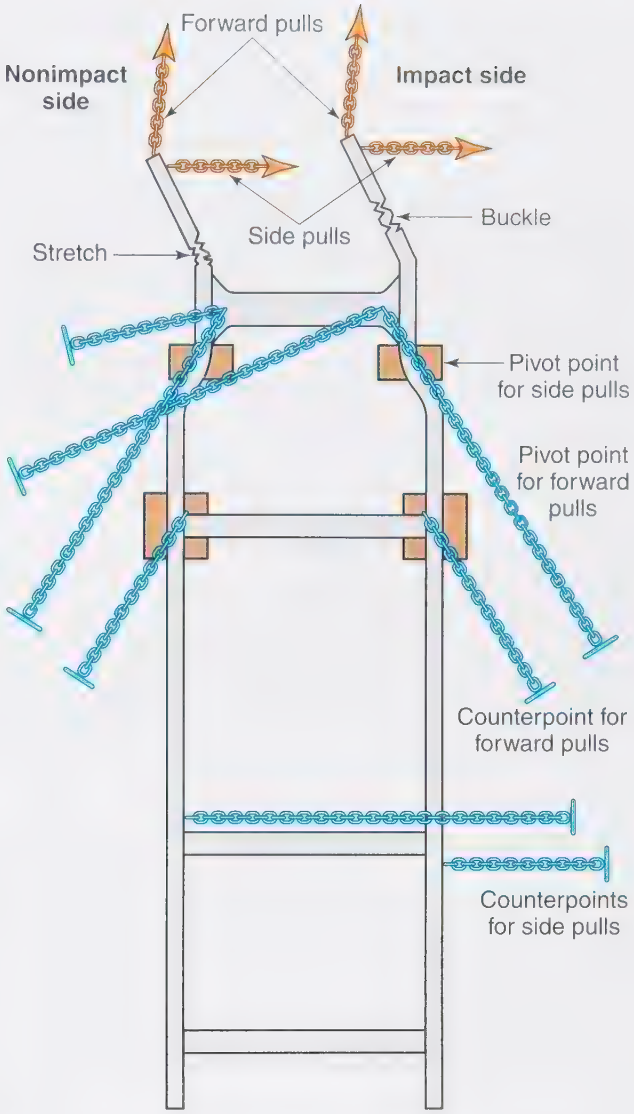

Forward pulls
Nonimpact side
Impact side
Buckle
Side pulls
Stretch
Pivot point for side pulls
Pivot point for forward pulls
Counterpoint for forward pulls
Counterpoints for side pulls

Figure 16-50. *The buckle and stretch are corrected with a combination of side and forward pulls with heating and hammering.*

NOTE

If heating is not allowed, the buckles will probably crack when they are pulled. A cracked frame that cannot be heated or welded must be replaced.

Once the impact rail buckle has been straightened, hook up and pull the nonimpact rail. As with the impact side, the side pull is first. As the broken edges of the flanges start to move, heat the flanges and the corners of the rail. Because the collision force on the nonimpact rail flanges caused them to stretch to the breaking point, the flanges must be shrunk to allow the frame to be straightened. When the broken edges of the flanges touch, stop pulling. Heat the edges of the broken flanges to cherry red. Stress relieve the adjacent metal with hammering. Make the forward pull. As the heated area cools, continue hammering. Once the flanges have cooled, use a thick cut-off wheel to make a clean cut where the broken edges meet. The frame will need to be reinforced and welded. Chapter 17 details the procedure for reinforcing and welding cracked full frames.

WORKING SMART

If the flanges on the nonimpact side did not separate, the metal was stretched but not to the breaking point. Shrink the stretched metal while pulling the rail into place.

Repairing a Rolled Rail

A frame rail can roll in from a side impact. See **Figure 16-51**. Two ways to straighten rolled rails are shown in **Figure 16-52**. In **Figure 16-52A**, the bottom of the box rail is held in place with a tie-down. In this example, the tie-down is an L-hook. Another L-hook is attached to the top of the rail. The upper L-hook is pulled.

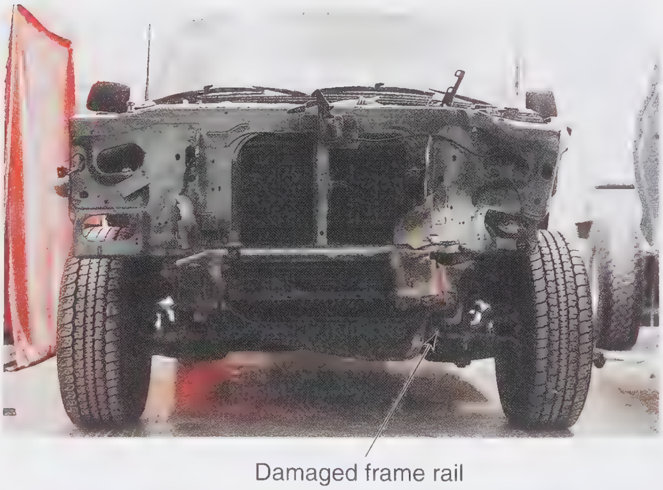


Figure 16-51. *This frame rail has been moved toward the centerline and rolled by a side impact.*

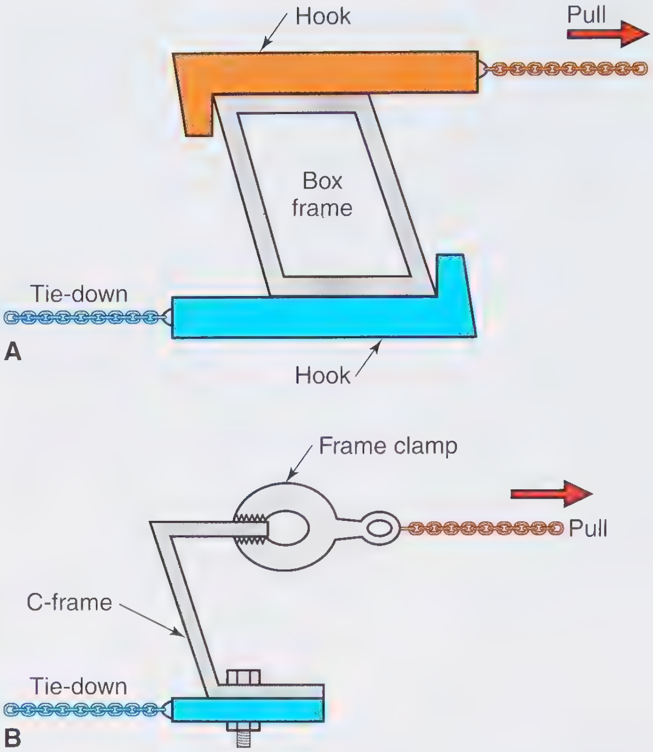


Figure 16-52. *A—Hooks are placed at the top and bottom of the rolled rail. The bottom hook is tied down. The upper hook is pulled in the direction opposite the tie-down. B—A bar is bolted to the bottom flange of the C-frame, and a clamp is installed on upper flange. The bar is tied down and the clamp is pulled.*

The tie-down and hookup should be placed on the corners. Make sure the hooks have a good bite on the metal. Otherwise, they can easily slip off.

In **Figure 16-52B**, a rolled C-channel frame rail is being repaired. Note that a bar bolted to the bottom flange serves as the tie-down. A clamp is used for the hookup, attaching the pull to the top flange of the rail.

Repairing a Collapsed Cross Member

A side impact can cause a cross member to collapse. To repair this type of damage, make a side pull while pushing up on the cross member at the same time. See **Figure 16-53**. Before pulling, tie-downs should be made in the four corners of the center section. The tie-downs should prevent sideways, downward, and upward movement. A chain basket hookup is made around the cross member as shown in **Figure 16-53A**. A side pull is made from the chain wrap. If the nonimpact side rail is not moved, it should be tied down so the force is concentrated on the

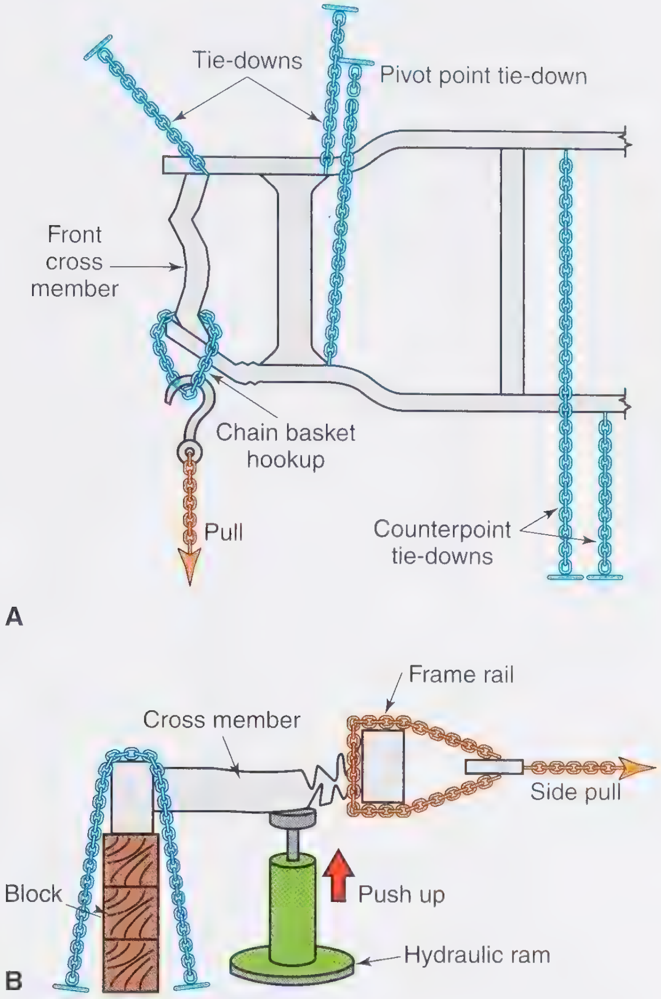


Figure 16-53. *In this example, a collapsed cross member is repaired by a side pull and upward force from a hydraulic ram. A—Top view. B—Front view.*

damaged rail and the cross member. As the damaged rail moves out, the cross member should be raised using a 10-ton hydraulic ram, **Figure 16-53B**. With the rail and cross member under tension, the corners of the rail and cross member should be stress relieved.

WORKING SMART

Do not try to straighten a damaged engine cross member. Engine cross members are extremely strong and have a multi-angled, complex shape. Replace the frame instead of attempting repair.

Repairing Widening

During a collision, the impact force traveling through the vehicle's frame may cause the frame rails to move away from each other. This condition is called ***widening***. To correct widening, the rails are pulled together. **Figure 16-54** shows opposing side pulls being used to correct widening. No tie-downs are needed. The frame rails are wrapped with a chain, the left rail is pulled to the right, and the right rail is pulled to the left.

Repairing Sidesway

Sidesway is a common type of frame damage. One type of sidesway is shown in **Figure 16-55**. In this example, one rail is moved toward the center of the vehicle. The cross member is damaged, but the nonimpact rail has not moved. In this type of repair, there will be five tie-downs. One tie-down will be

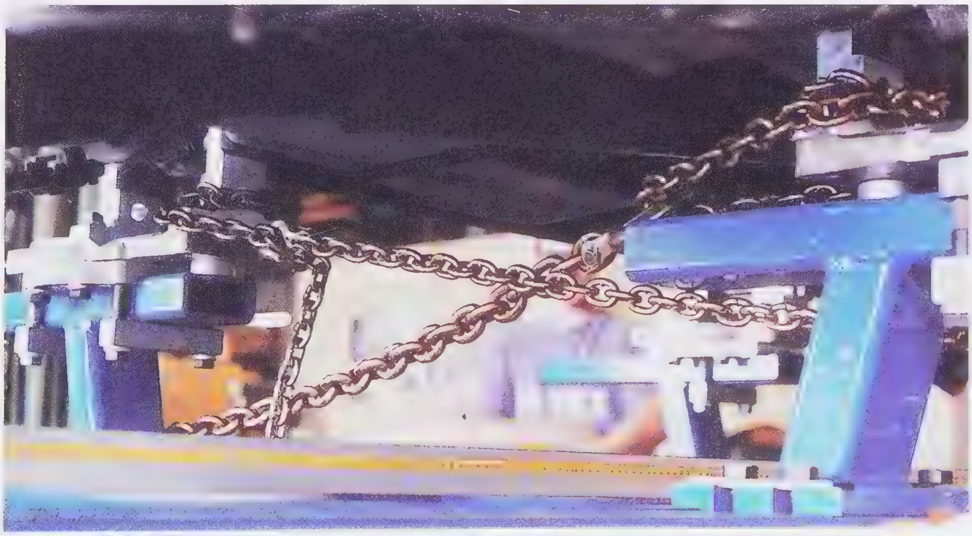


Figure 16-54. *The full-frame clamps are used as hookups to pull the frame rails together. Opposing side pulls bring the rails together.*

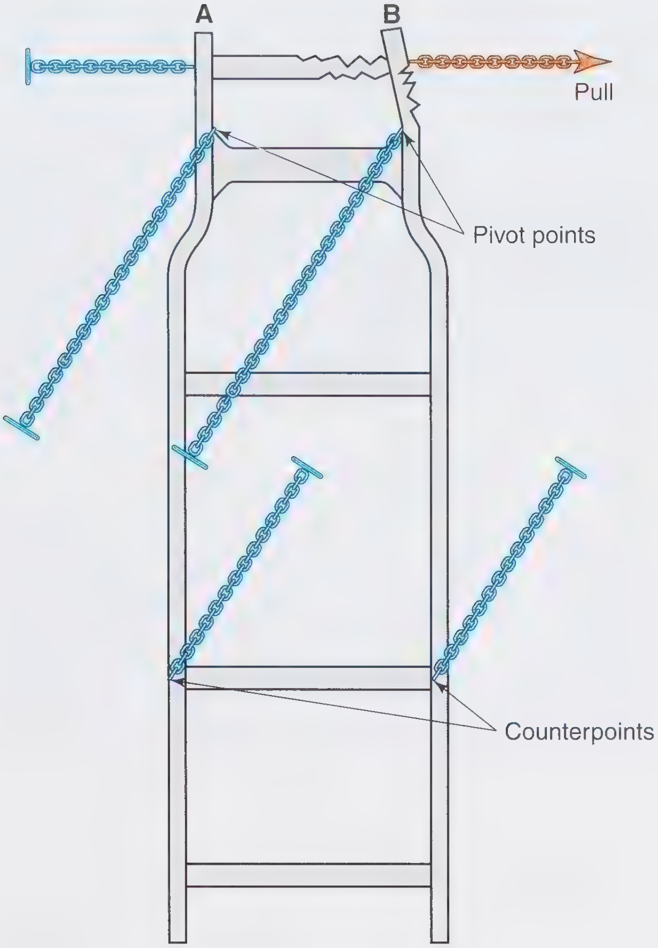


Figure 16-55. *A side pull is made on a full frame. The tie-down at A prevents movement of the left rail. The pivot points also prevent side movement while the counterpoints prevent spin.*

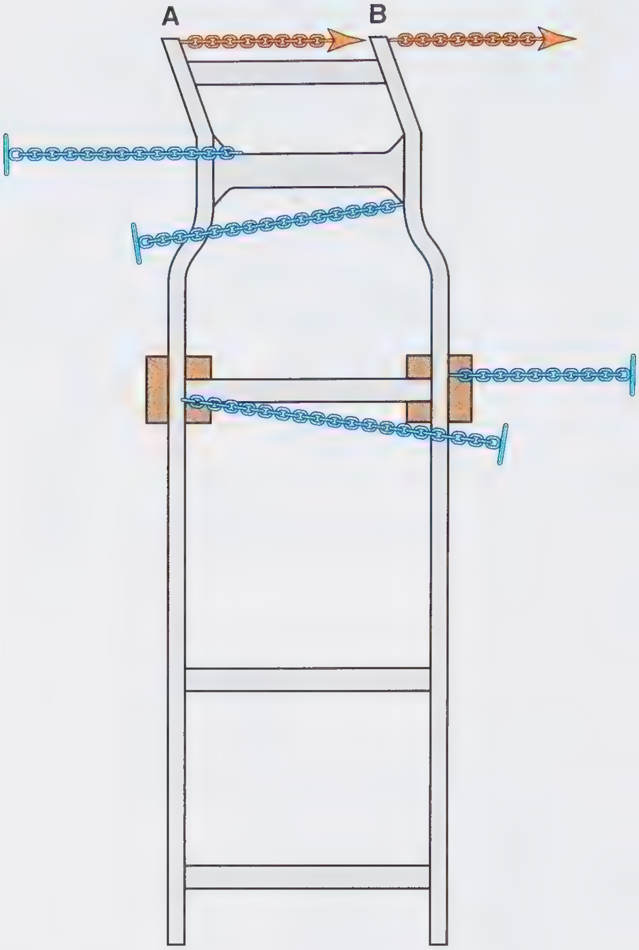


Figure 16-56. *Pull B first, and then pull A. Pulling A before B will cause the cross member to collapse.*

placed on the front of the vehicle at the undamaged rail. This prevents the rail from moving. The tie-down at the engine cross member on the impact side acts as a pivot point. The remaining tie-downs prevent movement of the rest of the vehicle. Blocking at the tie-downs prevents a change in height. If the cross member is collapsed, it should be raised as the pull is made. The side pull will align the rail and the cross member. The rail and cross member should be stress relieved while they are under tension.

Another type of sidesway is shown in **Figure 16-56**. There are four tie-downs. The tie-downs at the engine cross member act as pivot points. The rear tie-downs act as counterpoints. The cross member is not damaged. The pull can be made on one or both rails. When pulling both rails, make a chain wrap hookup on each rail. In this method, the pull at *B* should be made first, and the pull at *A* should follow. If *A* were pulled first, the force of the pull would tend to collapse the cross member.

When pulling on only one rail, a 10-ton hydraulic ram can be placed between the rails at the cross member. This will strengthen the cross member. As *A* is pulled, it will push on *B*.

A third type of sidesway is caused by a center impact. In this type of damage, the end sections have been moved toward the point of impact because the center section has been shortened on one side. The repair setup for this type of damage is shown in **Figure 16-57**. Note that the end sections are being moved back into place, thereby straightening the center section. One tie-down is made on the nonimpact side to oppose the side pull on the impact site. The end sections are pulled at 45° angles away from the impact site. As the end sections begin to move, the pull at the impact site should begin. These pulls will restore the length of the rail.

Some frame machines do not have provisions for three pulls. If only two pulls are available, make a tie-down on one end section instead of a pull. If only one pull is available, make tie-downs on the end sections and pull out at the center.

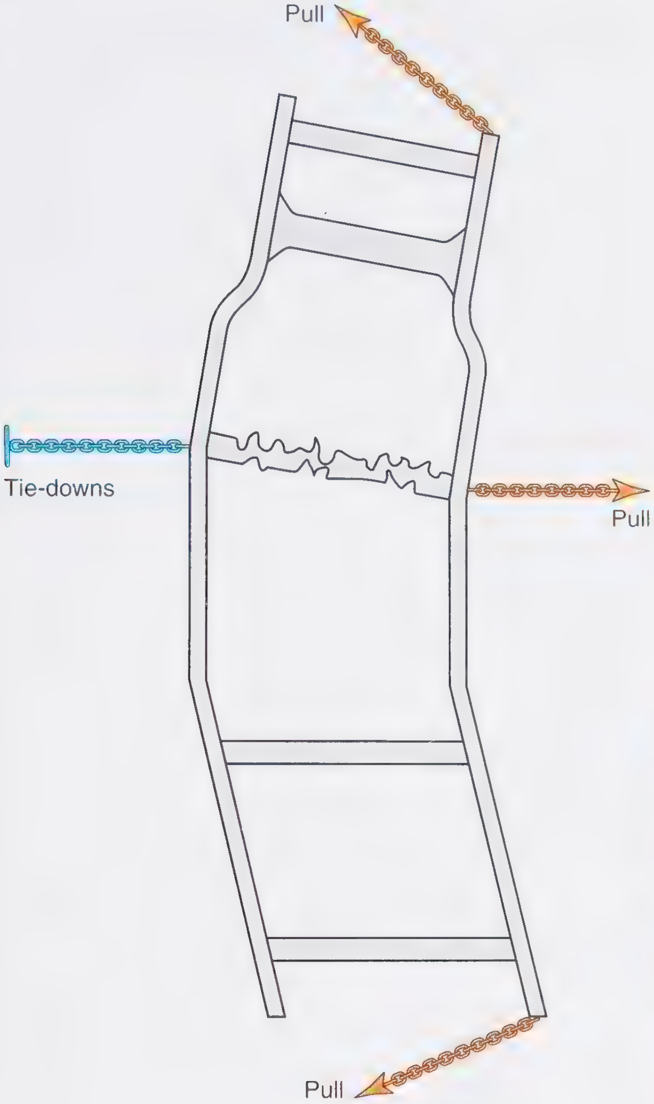


Figure 16-57. *Both end sections have moved toward the impact side. The end sections need to be moved back as the damaged rail is pulled out.*

Repairing Sag

Sag is present when a portion of a damaged frame is lower than the specified height. To correct sag, the damaged portion of the frame should be pushed or pulled upward. In most repairs, the sag damage is pushed upward.

Sag is common at the end of a rail. A tie-down should be placed at the damage site to prevent upward movement. The tie-down acts as a pivot point. Counterpoint blocking should be placed away from the pivot tie-downs to prevent the rail from moving down as the opposite end is raised. If both rails are sagged, they both should be tied down at the damage. If only one rail is sagged, the damaged rail should be tied down with a pivot point to make the bending occur at the damage. The undamaged rail should be blocked at the proper height and tied down so it cannot move up. This will concentrate the upward force on the buckle in the sagged rail.

Figure 16-58 shows a setup that will raise one sagged rail. In this case, a hookup is not needed because a hydraulic ram is used to raise the rail. The corner or corners of the rail are stronger than the other parts of the rail. Be sure the force is on the corner or corners, so you do not crush the rail.

Repairing Kickup

Kickup is a condition in which a rail is higher than the specified height. To correct kickup, the frame must be blocked near the damage. The blocking acts as a

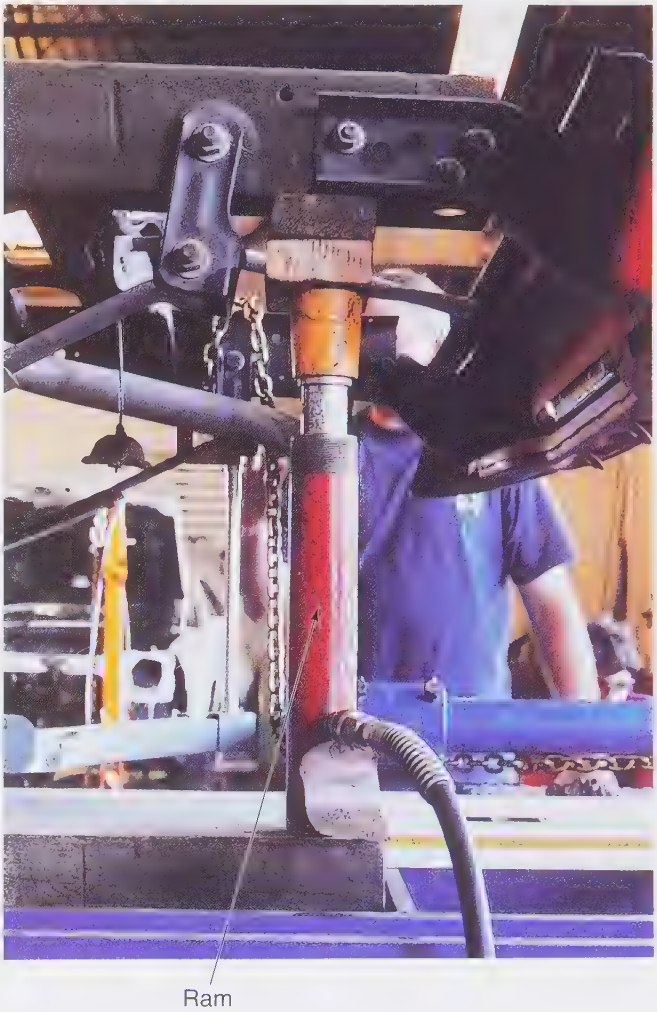


Figure 16-58. *A hydraulic ram is used to push up the left frame rail on this vehicle.*

pivot point. The rail is pulled down so the pull force causes bending at the pivot point. **Figure 16-59** shows a downward pull.

As with sag correction, if both rails need correction, they should both be blocked and pulled. However, if only one rail needs to be pulled down, the other rail should be blocked at the proper height. Counterpoint tie-downs must be placed to prevent the frame from moving up as the opposite end is moved down.

Repairing Twist

Twist is present if the four corners of the center section of the vehicle are out of level because one rail is pushed up and the other rail is pushed down. The out of level condition in the center section will cause an out of level condition in the end sections. Twist should be corrected in the center section, **Figure 16-60**. The frame under the cowl should be blocked at the proper height. At the rear of the center section, the low corner should also be blocked at the proper height. The high corner at the cowl should be tied down so it cannot move up. A down pull is made on the high corner at the rear of the center section. During the down pull, the bending in the center section corrects the damage.

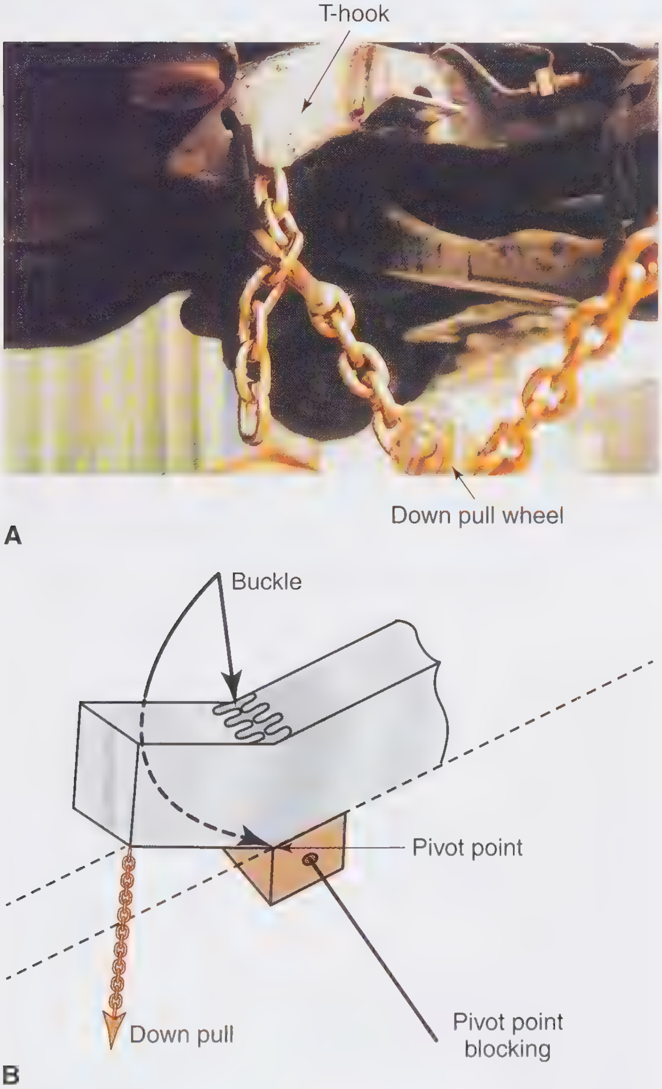


Figure 16-59. *A—This down pull is made with a T-hook inserted into a frame hole. Notice the down pull wheel in the foreground. B—The pivot point concentrates the pull on the buckle.*

Repairing Diamond Damage

Diamond damage affects the center section of the vehicle. In one type of diamond damage, impact on one rail causes the end sections to move. The front section moves toward the impact side, while the rear section moves away from the impact side. Diamond damage will not necessarily cause buckles in the frame. To correct

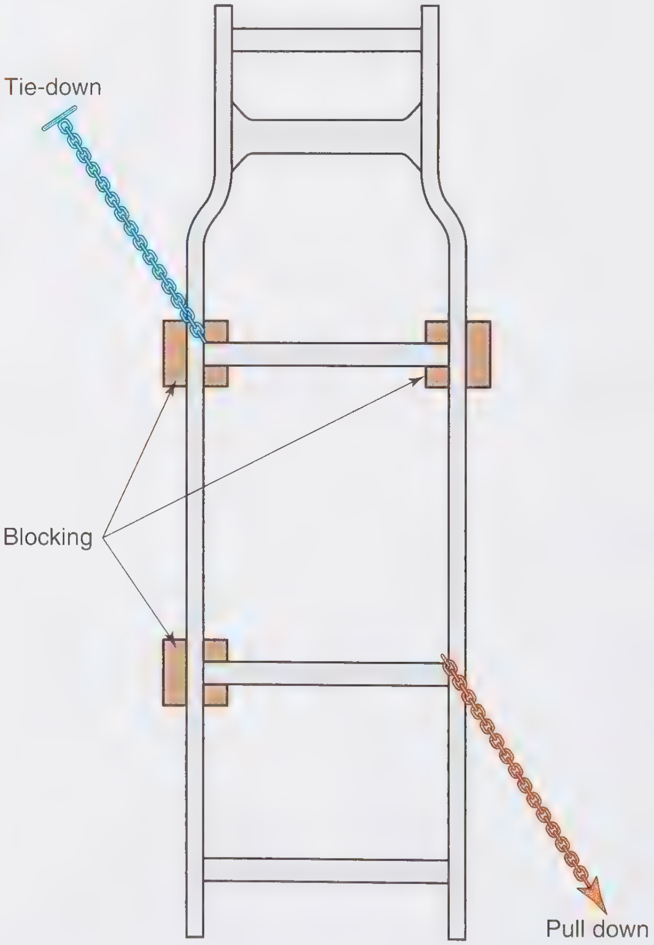


Figure 16-60. *An upper view of the twist repair plan.*

this type of damage, the center section is pulled in a way that allows the end sections to move back to their proper locations.

Figure 16-61 shows a setup for correcting diamond damage. Because there is no change in height, the four corners of the center section are blocked at the same height. An angle tie-down is made at the rear corner of the center section on the side opposite the impact. Another tie-down is made at the front corner of the center section on the nonimpact side of the vehicle. Angle pulls are made at the front corner of the center section on the impact side. These pulls cause the rear section to move toward the impact side because the frame rail moves forward. The pulls also push the front section away from the impact side because the frame rail on the impact side moves forward.

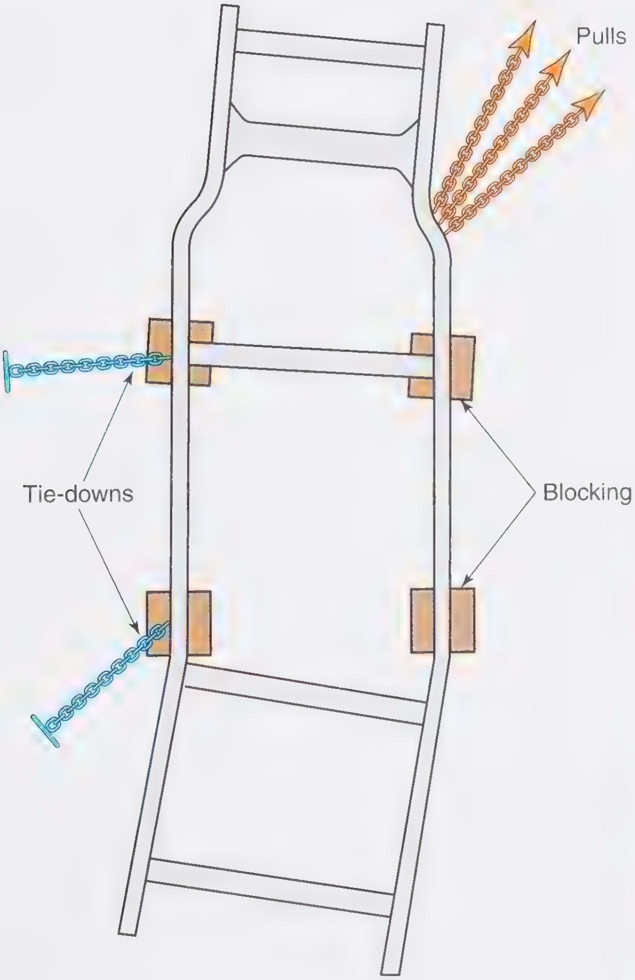


Figure 16-61. *To correct diamond damage, the center section of the vehicle is squared. Squaring the center section causes the end sections to rotate back into alignment. (Chief Automotive Systems)*

After the front and rear sections have been aligned, stress relieve the frame corners. Then, hammer on the rivets that hold the cross members to the frame. Finally, loosen and then retighten any bolted cross members. When the stress relieving is completed, release the tension on the frame. If the frame springs back into a diamond, repeat the pulling process. This time, over pull the damage and then stress relieve. After the diamond is removed from the center section, the damage in the end sections can be corrected.

Diamond damage may also be found where the front section is pulled toward the impact side, but the rear section is not moved away from the impact side. In this type of damage, pulling on the front damage will remove the diamond. To make this type of repair, block the rails at the proper height and put tie-downs at the front and rear corners of the nonimpact side. If a buckle is present at the cowl area on the impact side of the frame, tie down the damaged rail at the front and rear of the center section. Pull out the buckle. After the buckle has been removed, release the tie-downs on the damaged rail and make forward pulls to square the center section. Stress relieve the frame rail corners, cross member rivets, and bolted cross members. Once the diamond has been repaired, tie down the center section and repair the front section.

Repairing Mash

Mash causes a shortening of rail length. A double-folded buckle consists of two adjacent buckles. The double-folded buckle, shown in **Figure 16-62**, is an indication of mash.

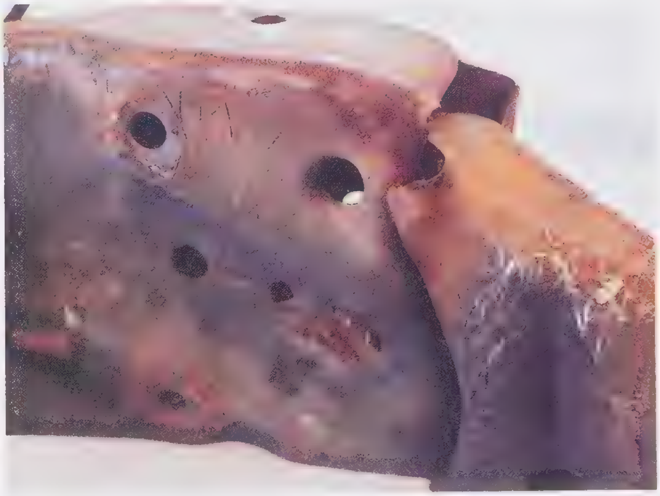


Figure 16-62. *This frame rail has mash. Notice the double fold.*

To repair mash, first determine if the manufacturer allows heating of the rail. If no heating is allowed, the rail may crack during repair. Tie down the rail as close to the mash as possible. Include blocking to prevent a change in height. Make one hookup as close to the mash as possible and another at the damaged end of the rail. Pull the damaged rail forward.

If heating is allowed, heat the buckles to the maximum temperature. Apply more tension as the buckles unlock. Stress relieve the corners of the rail. If heating is not allowed, use vibration to relieve stress. If the rail cracks, check the manufacturer's recommendations on frame welding.

Repairing Combination Damage

Combination damage means that two or more damage conditions are present in one vehicle. Quite often, damaged full-frame vehicles have combination damage rather than just one type of damage. If possible, tie-downs, hookups, and pulls are positioned to correct multiple types of damage at once. If front-end damage is found with twist damage, an example of combination damage, the vehicle can be repaired as shown in **Figure 16-63**. The frame is blocked at the proper height under the cowl. The low corner at the rear of the center section is also blocked at the same height as the cowl. An angle tie-down is made at the low rear corner. A tie-down is also made at the high rear corner. As forward pulls are made on the front of the vehicle, the frame behind the pull moves down. The purpose of blocking is to prevent this downward movement. If the blocking is not placed under the frame at a tie-down, the frame will move down at the tie-down during the forward pulls. Placing a tie-down without blocking at a high corner if the cowl is blocked will cause the high area to move down during a forward pull, correcting twist.

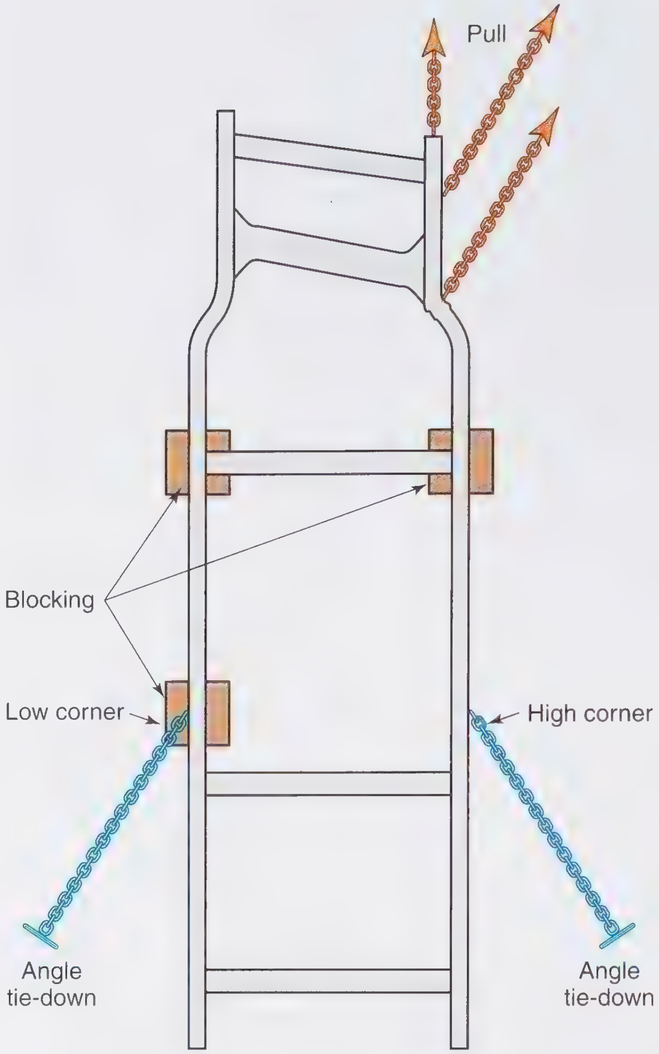


Figure 16-63. *In this twist correction, the cowl corners are blocked at the proper height. At the rear of the cab, the low corner is blocked and held while the high corner is held but not blocked. Pulling on the front of the vehicle will tend to lower the high corner, raise the low corner, and correct the twist. (Chief Automotive Systems)*

Since the frame rails at the cowl are blocked at the proper height, bending the rear area of the center section will set the frame rails at the cowl at the proper height also. If additional pulls are needed after the twist is corrected, the center section should be blocked and anchored. Hammer on the cross members, as well as the rivets and welds that hold the cross members to the frame rails, with the frame under tension. If bends are present on the cross members, hammer the bends out.

Figure 16-64 shows a pickup truck that was hit hard on the right front corner. This vehicle has all types of frame damage: twist, diamond, mash, sag, and sidesway. There is a buckle in the frame rail under the cowl. **Figure 16-65** shows the plan to correct the damage. The damage is corrected in two setups. The first setup straightens the center section of the vehicle. The twist and diamond are removed as shown in **Figure 16-65A**. Part of the buckle is removed by the forward pulls. Correcting the twist repairs the sag and kickup at the front and rear of the vehicle, except the kickup on the right front. The aligned center section is tied down so it cannot move. The sidesway misalignment is greater than the kickup, and a buckle remains on the right frame rail. The setup in **Figure 16-65B** shows a side pull to unlock the remains of the buckle and side and forward pulls to correct the sidesway, as well as the mash at the buckle. The last pull is a down pull to correct the kickup on the right front. Blocking is installed under the left frame rail and the down pull is made on the right rail.

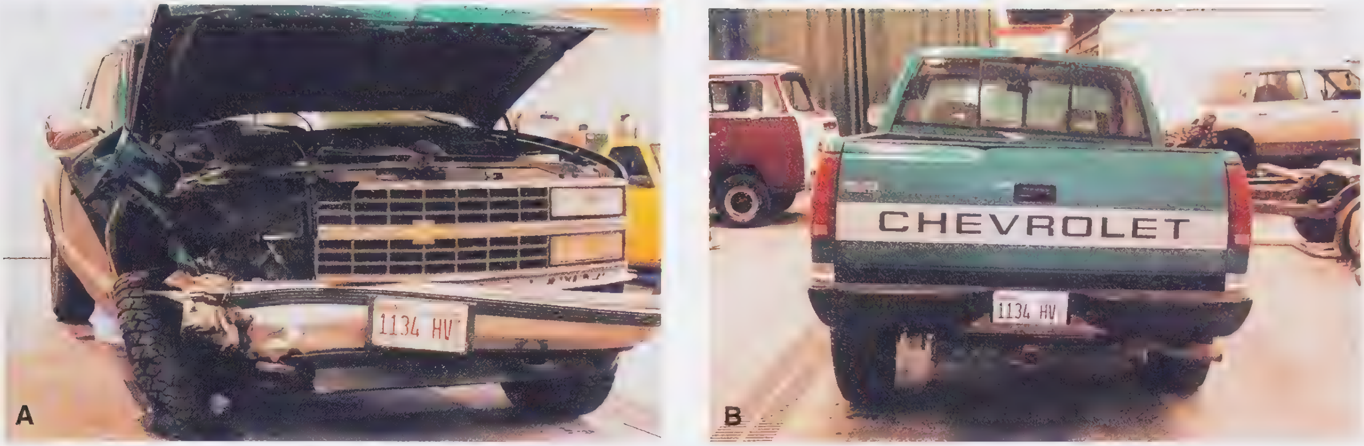


Figure 16-64. *This pickup truck has all the types of frame damage.*

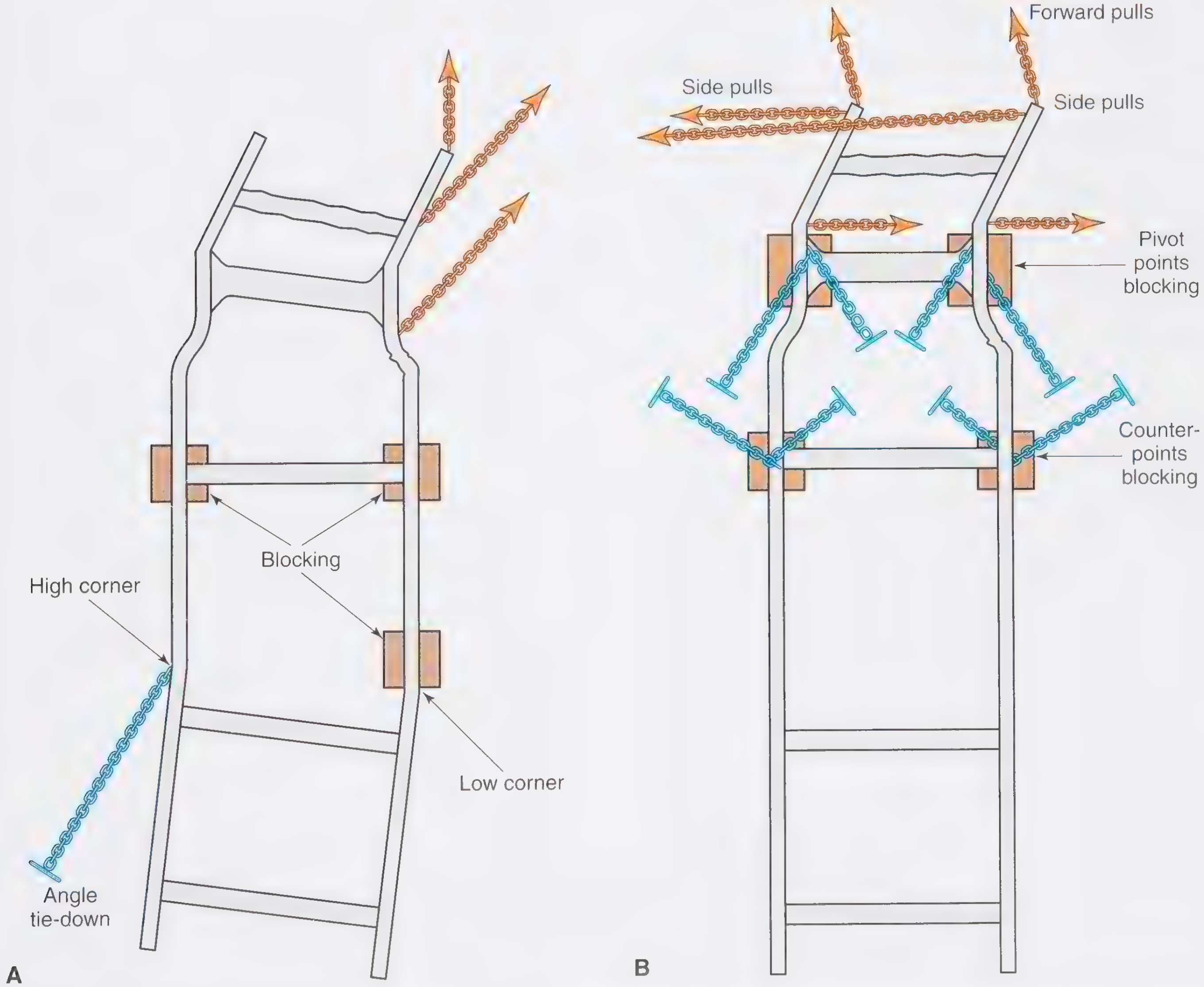

Blocking
High corner
Low corner
Angle tie-down
A
Side pulls
Forward pulls
Side pulls
Pivot points blocking
Counter-points blocking
B

Figure 16-65. *A—To repair twist and diamond, block the cowl and the low corner. Put a tie-down but no blocking at the high corner. Angle pulls are made in the damage area. B—The second setup corrects the remaining sidesway and mash.*

Summary

- Full-frame repair can be complicated when viewed as an entire project. However, if the project is broken down into individual steps, the steps themselves are relatively simple.
- A pull always tries to make a straight line between itself and the tie-down. The force of the pull acts on the tie-down. Therefore, the tie-down must be stronger than the pull.
- Frame repairs should not begin until all damage has been identified. Careful measurement will allow you to identify misaligned portions of a vehicle's frame.
- The tolerances for a full-frame vehicle are ±1/4" (±6 mm) for linear measurements and ±1/2" (±12 mm) for x-checks.
- Pivot point tie-downs prevent movement so the frame will bend at the desired location during the pull.
- A counterpoint tie-down is positioned away from the damage and prevents vehicle movement during a pull.
- Blocking prevents a change in height or acts as a fulcrum when a change in height is needed.
- To spread out the force of the pull, each tie-down should be equally tight.
- Hookups attach the pull to the frame. Hookups must be stronger than the damage. If they are not, the hookups will give way before the damage moves.
- To prevent damage to the frame, use multiple hookups whenever possible. This will help spread the force of the pull.
- Pulls are used to move a damaged frame to its correct location. The direction of the pulls and the number of pulls are important.
- Several pulls working together are called multiple pulls. Simultaneous multiple pulls in the same direction will spread the pull force over a large area, lessening the chance of damage to an area.
- Pushing with a hydraulic ram can correct sag or sidesway. A push with a hydraulic ram can also form a pivot point.
- Stress relief is performed when the vehicle is under pulling tension.
- When using vibration for stress relief, hammer on the flanges, angles, and corners of the frame. Also hammer on the rivets that hold the cross members and spring mounts to the frame.
- Mild steel frames can be heated as part of the stress relief process. High-strength steel frames should be heated only if recommended by the manufacturer.
- Spring back is the tendency of the frame to return to its damaged state once tension is released.
- Overpulling may be needed to compensate for spring back. Overpulling involves pulling a damaged frame rail slightly past its proper location.
- Various combinations of tie-downs, hookups, and pulls are used to repair different types of full-frame damage. Because all full-frame parts are connected, more than one type of damage is generally present.

Review Questions

Please do not write in this textbook. Place your answers on a separate sheet of paper.

1. Explain the two purposes of a tie-down.
2. The two types of tie-downs are pivot point tie-downs and ______ tie-downs.
3. Blocking acts as a(n) ______ when a change in height is needed.
4. Full-frame clamps act as both ______ and ______.
5. Pull force will be concentrated at the tightest tie-down. True or False?
6. In a(n) ______ hookup, the chain is looped around a cross member and tied to itself.
7. Multiple hookups mean that more than one hookup is made on one pull. True or False?
8. Explain one method used to prevent the collapse of a C-channel frame when using a chain-wrap tie-down.
9. A single wrap of 1/4" frame can be used as a tie-down. True or False?
10. A(n) ______ pull is perpendicular to the frame rails and used to restore width.
11. Explain what the phrase *multiple pulls* means.
12. The two methods of stress relief are ______ and ______.
13. When stress relieving, an area ______ times the size of the buckle should be heated.
14. The frame will return to its damaged state if grain misalignment is not corrected. True or False?
15. Center section misalignment is corrected last. True or False?
16. Which is restored first: length, centerline, height, or width?
17. Explain why a frame is overpulled.
18. The cross member should be pushed up when repairing a collapsed cross member. True or False?
19. What type of damage is present when the corners of the center section are not level?
20. Explain how to repair mash.

ASE-Type Questions

1. Technician A says that the tolerance for linear measurements is ±1/2" for full-frame vehicles. Technician B says that tolerance for x-checks is ±1/4" for full-frame vehicles. Who is right?
   (A) A only.
   (B) B only.
   (C) Both A and B.
   (D) Neither A nor B.
2. Technician A says that pivot-point tie-downs are positioned at the damage. Technician B says that counterpoint tie-downs are positioned away from the damage. Who is right?
   (A) A only.
   (B) B only.
   (C) Both A and B.
   (D) Neither A nor B.
3. Technician A says that multiple hookups spread the pull force over a larger area. Technician B says that multiple hookups are preferred to a single hookup. Who is right?
   (A) A only.
   (B) B only.
   (C) Both A and B.
   (D) Neither A nor B.
4. All of the following pulls are level to the floor EXCEPT:
   (A) a straight pull.
   (B) a side pull.
   (C) an upward pull.
   (D) an angle pull.
5. All of the following should be followed when heating a frame EXCEPT:
   (A) heat an area 1–2 times the size of the buckle.
   (B) heat the corners only.
   (C) gradually raise the temperature.
   (D) heat with the frame under tension.
6. Technician A says that overpulling will always compensate for spring back (settle back). Technician B says that overpulling is not needed. Who is right?
   (A) A only.
   (B) B only.
   (C) Both A and B.
   (D) Neither A nor B.
7. Two buckles are present on a frame rail. Technician A wants to repair the buckle nearest to the direct damage first. Technician B wants to repair the buckle furthest from the direct damage first. Who is right?
   (A) A only.
   (B) B only.
   (C) Both A and B.
   (D) Neither A nor B.
8. A C-channel frame has sidesway in both frame rails. Technician A says that the nonimpact rail will have stretching on the flanges. Technician B says that the impact side will have buckles on the flanges. Who is right?
   (A) A only.
   (B) B only.
   (C) Both A and B.
   (D) Neither A nor B.
9. What type of damage requires three pulls: a 45° angle pull on the front section, a 45° angle pull on the rear section, and a side pull on the center section?
   (A) Diamond.
   (B) Sidesway in the center section.
   (C) Twist.
   (D) Sag.
10. One rail has sag. Technician A wants to tie down both rails. Technician B wants to tie down the damaged rail only. Who is right?
   (A) A only.
   (B) B only.
   (C) Both A and B.
   (D) Neither A nor B.
11. A vehicle has twist. Technician A wants to tie down the high corner of the cowl. Technician B wants to block the low corner at the rear of the center section. Who is right?
   (A) A only.
   (B) B only.
   (C) Both A and B.
   (D) Neither A nor B.
12. All of the following damage is caused by a change in height EXCEPT:
   (A) diamond.
   (B) twist.
   (C) sag.
   (D) kickup.
13. A vehicle has diamond damage. Technician A wants to tie down the center section of the nonimpact side. Technician B wants to tie down the center section of the impact side. Who is right?
   (A) A only.
   (B) B only.
   (C) Both A and B.
   (D) Neither A nor B.
14. Diamond damage is being discussed. Technician A says that diamond damage affects the center section of the vehicle. Technician B says that diamond damage always causes buckles in the frame. Who is right?
   (A) A only.
   (B) B only.
   (C) Both A and B.
   (D) Neither A nor B.
15. Which of the following damage is present when the frame has a double-folded buckle?
   (A) Diamond.
   (B) Twist.
   (C) Mash.
   (D) Sidesway.

SUPER ROTAX

The replacement of structural components can proceed only after the damaged vehicle has been pulled back to factory specifications.

Chapter 17

Structural Component Replacement

Objectives

After studying this chapter, you will be able to:

- Explain full replacement with new parts on unibody structural panels.
- Explain sectioning procedures with new parts on unibody structural panels.
- Explain sectioning procedures on full-frame structural parts.
- Explain sectioning procedures with salvaged parts on unibody structural panels.
- Explain rustproofing operations.

Technical Terms

clip
epoxy primer
front clip
front section
full replacement
hat channel
high-density foam
low-density foam
plug welds
rear section
rear section and roof or rear clip top
salvaged part
seam sealer
sectioning
side clip
side section
skip welds
stitch welds
structural components
wax-based rustproofing

Introduction

The strength of a vehicle is dependent on the integrity of structural components. ***Structural components*** protect passengers during a collision and support the weight of the vehicle. Vehicle manufacturers' recommendations must be followed when repairing or replacing damaged structural components.

Structural Panel Replacement Procedures

Structural components are spot welded, continuously welded, or bolted in place at the factory. During replacement, proper procedures must be followed to ensure that the customer's vehicle will properly protect all occupants in the event of another collision, drive straight, and resist rust.

The sequence of operations that should be used when replacing a structural panel is as follows.

1. Disassemble.
2. Straighten.
3. Plan.
4. Remove the damaged panel.
5. Pretreat.
6. Fit up.
7. Join.
8. Rustproof and paint.
9. Replace foam.
10. Reassemble.

The following sections explain each of these ten replacement procedures in detail.

Disassemble

Bolted panels, such as fenders, hoods, bumpers, and doors, must be removed to allow access to the underlying structural parts. Mechanical parts, such as radiators, condensers, drive train components, and suspension components, may interfere with structural part replacement and may need to be removed as well. The windshield or back glass may need to be removed to gain access to structural parts. See **Figure 17-1**. Interior components such as the seats, trim, and carpet should be removed if the rocker panel, A-pillar, or entire front lower frame rail must be replaced.

Damage may limit access to fasteners or it may not allow movable parts, such as hoods and doors, to open. There are three solutions: cutting, pulling, and prying. In cutting, the damaged sheet metal is cut away for access to fasteners or latches. For example, if a smashed door will not open, cutting a hole in the outer panel will provide access to the rods that move and open the latch. When pulling, the damaged vehicle can be placed on a frame machine and tied down so a pull can be made on a damaged panel to allow access to fasteners or latches. In prying, a long steel bar can be used to pry on and release the latch.

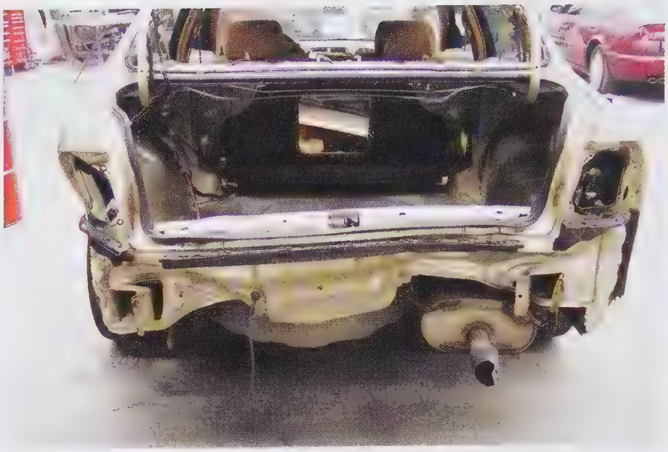


Figure 17-1. *The rear bumper, taillights, back glass, and deck lid have been removed from this rear side hit unibody vehicle.*

Straighten

All structural components should be aligned before damaged structural parts are removed. Accurate measurements will confirm that the parts are in alignment. On a unibody vehicle, the steering geometry is based on the position of the structural parts. Little, if any, adjustment is possible. The structural parts *must* be in the correct location for the vehicle to drive straight.

Measuring should be done before the vehicle is straightened and again after straightening is complete. Measurements should also be taken after new structural parts have been installed but before they are welded in place. This will allow for some adjustment before the parts are permanently welded in place. Measurements are also used to determine where to cut on damaged and replacement parts.

A unibody vehicle is designed to absorb collision force. The collision force can cause damage in areas far from the point of impact. Even though the damaged parts will be removed for replacement, they must be straightened first, before removal, so surrounding parts are in alignment and the new parts will fit properly. **Figure 17-2** shows an upper rail being straightened.

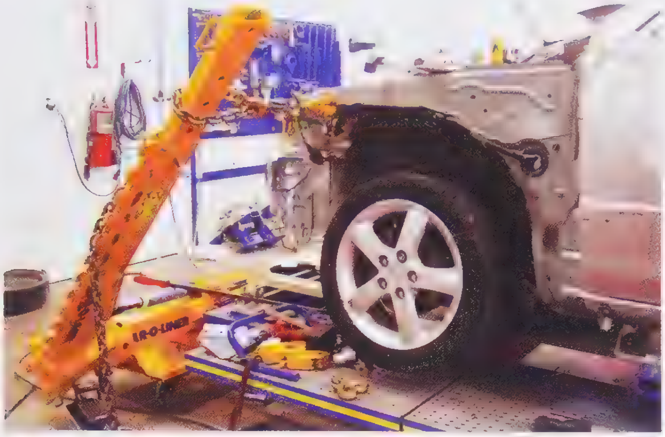


Figure 17-2. *Before the apron and radiator support can be replaced, the upper rail must be pulled to the proper location.*

Heat can be used to unlock buckles. Since the damaged panels will be replaced, overheating them is not a concern. Use the recommended stress relief procedure on panels that will not be replaced. Before or during pulling, it may be necessary to weld torn spot welds or unirail cracks to get the pull to relieve damage. Temporary welds can be made on panels that will be replaced.

Plan

Once the damaged components have been straightened and measured, you can plan the repair. You must determine whether a portion of a damaged structural part will be replaced or whether the part will be replaced in its entirety.

A structural component is often intertwined with several other panels. Removal of an entire structural panel at the factory seams, such as a front lower frame rail, may involve removing mechanical components, drilling out welds on adjacent panels, and destroying factory corrosion protection. In these instances, ***sectioning***, which involves removing and replacing only the damaged portion of a structural panel, may be the best way to make the repair.

The greatest concern when sectioning is maintaining the vehicle's structural integrity. A properly sectioned structural component will be as strong, vibration-resistant, and as safe as the undamaged factory-installed panel. A unibody vehicle's structural components are designed to protect the vehicle's occupants in a crash. In a front impact, some unibody structural components ahead of the shock towers are designed to crush, yield, or collapse to absorb collision energy. The timing of air bag deployment is dependent on the vehicle's structural components collapsing at the designed rate. In a collision, the sectioned panel must crush in the same way as an original panel. An improperly repaired vehicle, in which a structural component is not properly welded or rustproofed, will not collapse as designed and may transfer too much collision energy to the passenger compartment.

Other structural components, such as reinforcements, are designed to transfer energy. These components resist movement so other structural components do not intrude into the passenger compartment, protecting the vehicle's occupants during a collision. For example, the reinforced cowl protects occupants from injury in a front or side hit. In a rollover, the reinforced A-pillar must be able to support the entire weight of the vehicle to prevent the roof from collapsing on the occupants. An improperly repaired structural component may not be strong enough to resist movement.

Another consideration in sectioning is the presence of reinforcements inside components. Multilayer reinforcements are common in rocker panels, A-pillars, and center pillars. See **Figure 17-3**. These reinforcements may be made of advanced high-strength steel and cannot be sectioned.

Structural parts that are commonly sectioned include lower front frame rails, A-pillars, center pillars, rocker panels, and rear frame rails. The decision to section a panel must be made before any damaged panel is removed from the vehicle. The location of the sectioning joint is very important. For the sectioned panel to restore the vehicle's structural integrity, the sectioning joint must be made in the proper location. Some OEMs provide instructions with their replacement parts.

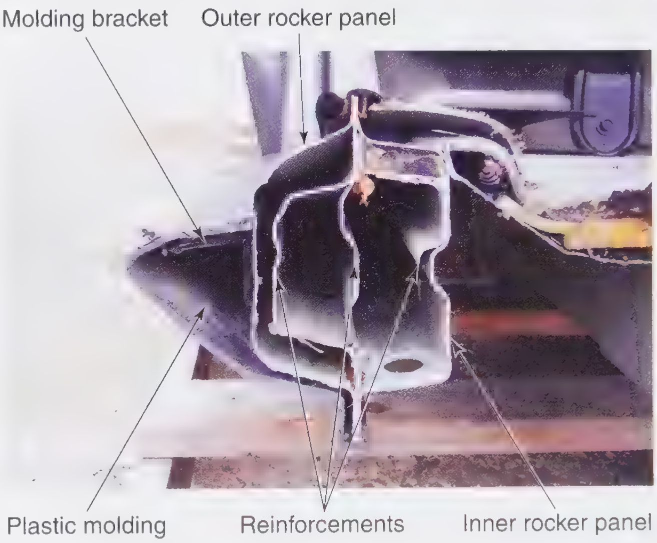


Figure 17-3. *Rocker panels may have several layers of reinforcements.*

See **Figure 17-4A**. The instructions give specific OEM-recommended procedures that should be followed when sectioning a structural part. Collision estimating guides may list some sectioning joint locations. Structural components, both the replacement part and the original part, may have a sectioning mark that indicates the correct sectioning location, **Figure 17-4B**. Sectioning information is available at I-CAR's website. Sectioning locations can also be found in manufacturers' collision repair guides.

For sectioning to work, the damaged frame or unibody must be straightened first. After straightening, all the damage must be cut off. Usually, only one sectioning location is specified for a given part. If damage extends into an area beyond the sectioning location, sectioning should not be done. Instead, the entire part should be replaced.

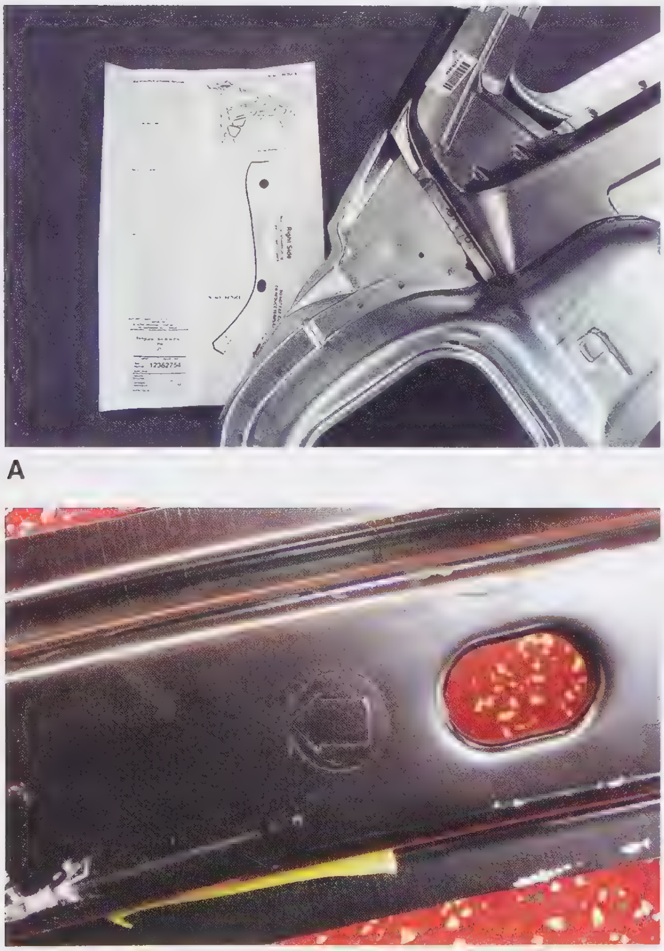


Figure 17-4. *A—Sectioning instructions are included with this replacement wheel house. B—The die mark on this replacement part indicates where the cut should be made for sectioning. The original part will also have a die mark at the sectioning cut location.*

Sectioning information may not be available for some vehicles. On these vehicles, the technician should use the following criteria to determine if and how to section a panel.

- All damage must be cut out when sectioning. No damage should extend into the part of the panel that will remain on the vehicle.
- No internal or external reinforcements at the section joint.
- Avoid suspension and drive train mounting locations.
- Avoid crush zones, such as folds, dimples, and holes.
- Avoid hinge locations, seat belt mounting points, and areas where horizontal and vertical panels meet.
- If a suitable area cannot be found, do not section the component. Replace the entire structural part.

Full replacement means that the entire structural panel is replaced. Examples of components that must be replaced in their entirety include the radiator support, front upper frame rail, outer rocker panel, and in some cases, front lower frame rails. The entire panel should be replaced if there isn't a factory-recommended sectioning location and if an acceptable sectioning location cannot be found. Some manufacturers require that all structural panels be replaced in their entirety.

Remove the Damaged Panel

The structural panels of a unibody vehicle are held together with welds. Most of the welds are spot welds, but some are continuous welds. Structural panels are removed by cutting out these welds.

Sectioning requires careful measurement of both the replacement part and the original part. Holes in the structural parts can be used as a reference for measurements. For example, the sectioning instructions may say to make a cut line 100 mm to the rear of the 32-mm oval hole. A tape measure can be used to determine the distance between the reference hole and the cut line.

A combination square can be used to transfer the cut line all the way around a rail. A line can be scribed or masking tape can be stretched from point to point to make a straight line. Both the replacement part and the original part can be trimmed with a cut-off wheel or a reciprocating saw. Accurate cuts will ensure a good fit up.

Regardless of whether a panel is sectioned or replaced in its entirety, the location of spot welds must be determined before the panel can be removed. One way to locate hidden spot welds is shown in **Figure 17-5**. Drive a chisel between the two panels. The panels will separate in areas where welds are not present. A spot weld will not allow the panels to separate.

Once the spot welds are located, they can be removed. Center punch the weld and drill a pilot hole at the punch mark. Then drill out the weld with a spot weld cutter bit. Cutting oil can be used on strong steel parts.

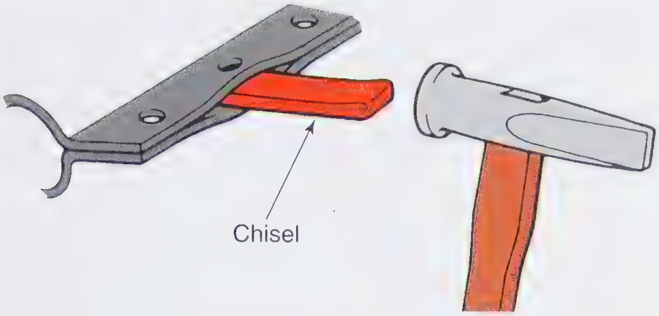


Figure 17-5. *The panels will separate between the spot welds when a chisel is hammered between the panels. (Toyota)*

A clamp-on cutter can also be used to remove spot welds. The clamp-on cutter is a drill that clamps in place at the spot weld. The drill spins a hole saw that cuts around the spot weld.

Sometimes, MIG plug welds must be removed, usually because a replacement part has been damaged in a subsequent accident. **Figure 17-6** shows a method for removing MIG plug welds. Drilling out the welds is not practical since the welds are extremely hard. Instead, the welds are ground out. To accomplish this task, use a cut-off tool and a thick disk. Grind on the weld, rocking the wheel in and out slightly. Do not press too hard on the grinder and stop grinding as soon as the outer panel has been penetrated.

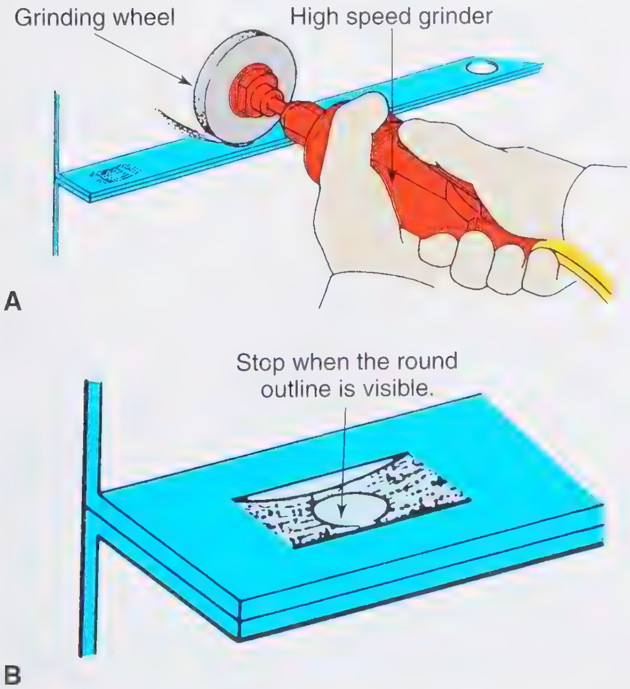

Grinding wheel
High speed grinder
A
Stop when the round outline is visible.
B

Figure 17-6. *MIG plug welds cannot be drilled out. Use a grinder to remove these welds. (Toyota)*

Use caution when the outer panel has to be removed but the bottom panel does not. Do not drill through the bottom panel. If you do make this mistake, you will not be able to weld onto the bottom panel. If the cutter has a depth-of-cut adjustment, set the depth to cut through the upper panel only. If the bottom panel is to be replaced and the outer panel is to be retained, drill through both panels. This not only allows the bottom panel to be removed, but it also creates the plug weld hole in the upper panel.

Remove continuous welds by grinding them with a cut-off wheel or a disk grinder, **Figure 17-7**. Grind on the weld only, not the surrounding metal. Do not cut into the underlying metal. When the welds are cut out, the damaged panel can be removed.

WARNING

Panel edges can be sharp. Wear gloves when handling the panels.

Pretreat

The purpose of the pretreat step is to prepare the surfaces of both the replacement part and the vehicle for fit up and welding. Pretreating involves the following steps.

- Removal of weld nuggets—If the outer panel is removed by drilling out the spot welds, the remaining underlying panel will have spot weld nuggets on it. These nuggets will interfere with fit up, and therefore, they must be removed with a grinder.

WARNING

Nugget removal requires careful attention—Never grind away metal from the bottom panel. Grinding away metal on the bottom panel will weaken the part. Grind on the nugget only. Tight corners may require the use of a small disk grinder or even a cut-off wheel.

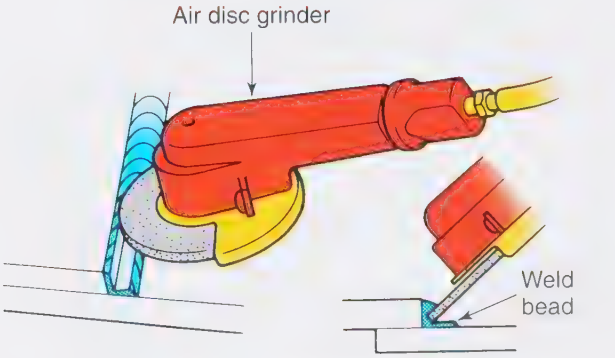


Figure 17-7. *Use a cut-off wheel or a grinder to remove continuous welds. Keep the cut-off wheel or grinder on the weld and avoid cutting the surrounding metal. (Toyota)*

- Make plug weld holes—If MIG plug welds will be used, make plug weld holes. Plug weld holes are not needed if STRSW will be used. Punch 5/16" holes for plug welds. As a rule of thumb, use the same number of plug welds as factory spot welds. However, if the manufacturer recommends a different number, follow the manufacturer's recommendations. Do not put the plug welds in the same locations as the factory welds.
- Clean weld surfaces—Use a wax and grease remover to clean contamination from the surfaces to be welded. Contamination could be caused by oil, undercoating, or dirt.
- Remove paint—Good welding requires clean, bare metal surfaces. Remove paint or factory e-coat primer from the weld areas. To prevent removing metal with the paint, use a nylon abrasive disk. **Figure 17-8** shows this operation. Remove only enough paint to allow for proper welding. Do not remove galvanized coatings.
- Apply weld-through primer—Once panels have been joined with a lap joint or a butt joint with an insert, the internal surfaces, which must be bare for a good weld, are no longer accessible for priming. Bare metal in a weld area rusts rapidly, weakening a repaired unibody. Apply weld-through primer to bare metal in the weld area before joining the panels together. If a zinc coating is already present on the panels, weld-through primer is not required.
- Remove foam— Factory installed foam may be found inside vehicle body cavities. This foam will melt and release toxic fumes if heated above 515°F (300°C), so do not weld near it. If foam is in the splice panel, remove the foam so there is at least a 2" gap between the foam and the weld. You can replace the foam after repairs are completed.

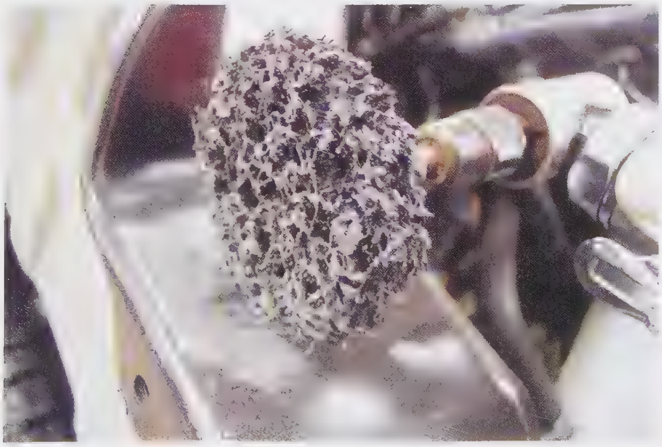


Figure 17-8. *Welding demands a clean, paint-free surface An abrasive disk will only remove paint, not metal.*

Fit Up

Replacement parts are positioned, measured, aligned, and installed in the fit up stage. The steps in the fit up stage are as follows:

- Positioning—Positioning involves placing a structural part where it belongs on the vehicle. The part can be held in place temporarily with locking pliers or clamps. See **Figure 17-9**. Positioning is temporary until the proper location can be verified.
- Measuring—The position of the replacement part is checked by measuring. If three-dimensional measuring is available, the proper positioning of parts on the lower body can be easily verified. If the vehicle is on a dedicated bench, the fixtures can be used to position parts. Hanging gauges and x-checks can also be used to check part position.
- Alignment—If measurements indicate that the parts are not positioned properly, the parts must align. Alignment means to move the part to its correct location. This generally involves releasing the pliers or clamps and moving the part into place. Continue the process of measuring and aligning until the part is in the correct location.
- Installation—When the part is properly aligned, 1/8" holes should be drilled in both panels. Sheet metal screws are then threaded into the holes. See **Figure 17-10**. The screws will make a tight fit up between the panels. On a butt joint with an insert, screws are the only way to get the replacement panel to fit tightly. After welding, the screws can be removed and the holes welded shut.

NOTE

On an A-pillar or a center pillar replacement, some technicians will temporarily install the doors to make sure they line up properly before welding.

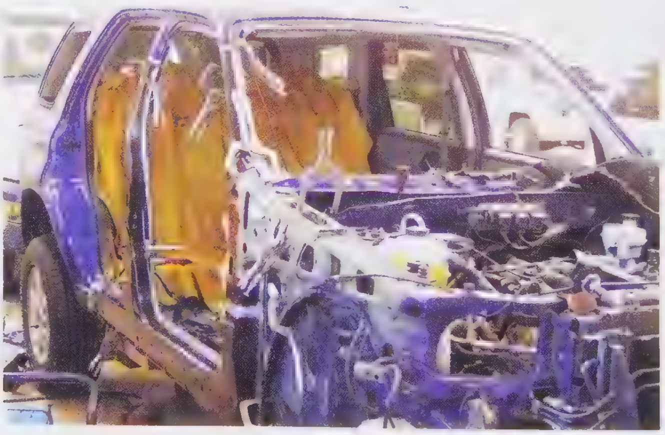


Figure 17-9. *The replacement panels are held in place with locking pliers.*

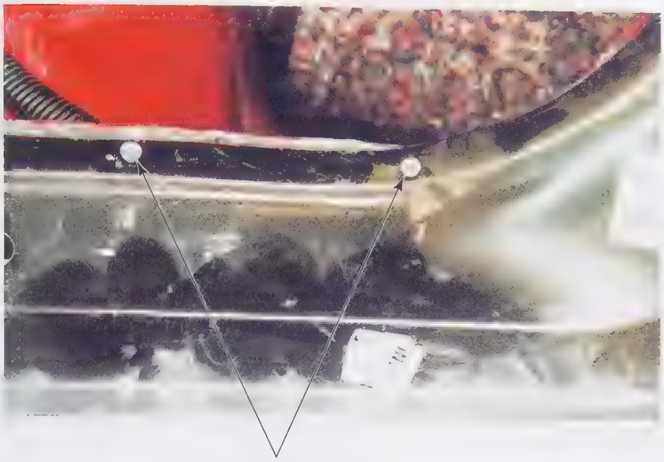


Figure 17-10. *Sheet metal screws hold the panels in place before welding.*

Not all shops have a 3D measuring system that will supply exact measurements of the upper body. In these instances, the only way to verify that the structural panels are properly positioned is to temporarily install the important parts and check for fit.

Join

The structural integrity of the vehicle is dependent on the strength of the welds. Most structural components will be joined by either MIG welding or Squeeze-Type Resistance Spot Welding (STRSW). Welding is the OEM-approved method of joining mild or high-strength steel repair components. Because laminated steel cannot be MIG welded or reached with the types of STRSW welders available to body shops, laminated steel components are joined by adhesives and rivets.

Replacement structural panels are installed with ***plug welds*** or continuous welds if a MIG welder is used. An STRSW welder may be used to make spot welds on panel edges. This welder will reduce the replacement time compared to MIG plug welding.

NOTE

Avoid making a weld over a previous OEM spot weld. At least one manufacturer recommends that the number of spot welds on a replacement structural panel be 1.3 times the number of OEM spot welds.

If the damaged component was weld bonded in place and MIG plug welding will be used to join the panels rather than STRSW and adhesives, the required number of plug welds in the proper places must be made. One manufacturer recommends making an extra plug weld in between each factory spot weld location. If these guidelines are followed, the number of MIG plug welds required is 2N minus 1, with N being the number of factory spot welds.

Automotive sheet metal is thin — typically, between 1/32" and 1/16". The heat levels needed to penetrate and bond metal this thin is low, but a continuous bead may concentrate too much heat in one place and cause strength loss and/or panel distortion. Before you begin, make a test weld on scrap metal the same thickness as your workpiece to verify welding machine settings.

A ***stitch weld*** is a short, but continuous bead about 3/4" long. The short bead length prevents the buildup of excess heat. Stitch welds can be joined together to make a continuous weld of any length.

Skip welding is another technique of spacing welds to minimize heat and balance the internal stresses caused by heating metal. This process helps disperse the heat created by welding as well as hold the metal in place without warping. ***Skip welds*** are shorter than a stitch weld. Skips welds are short, tack-like welds. The technician alternates welding sites so each welded area has time to cool down before welding is continued. This welding technique allows enough time for the surface to cool sufficiently before laying down another tack. The welds can be joined together to form a continuous weld.

There are several types of joint and weld combinations used to secure structural panels. These combinations are detailed in this section. The type of joint and weld is determined by the manufacturer's recommendations. The joint and weld combination must be as strong as an undamaged structural part.

- Lap joint/plug welds—This is a common procedure used in sectioning and full panel replacement. In this type of joint, the replacement panel can be on the top or bottom. Plug welds hold the panels together. See **Figure 17-11**. The plug weld hole is 5/16" in diameter. The edge of the hole is welded in a circle. If three layers of metal are to be plug welded together, the bottom layer will not have a hole. See **Figure 17-12**. Note that the middle piece has a standard 5/16" hole, while the upper piece has a 3/8" hole. This allows a larger plug weld at the top layer, tying the welds together. To make these welds, line up the panels. Make the plug weld at the middle and bottom pieces. When that weld is complete, make the plug weld to join the middle and top pieces.

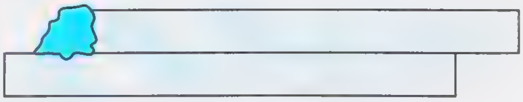


Figure 17-11. *Lap welds are common in structural component replacement. In this type of joint, the replacement panel can be on the top or bottom.*

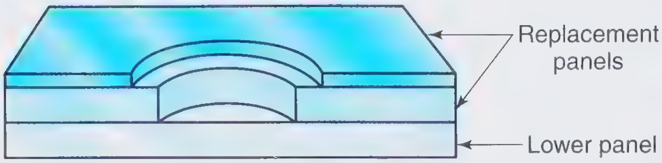


Figure 17-12. *If three panels must be plug welded together, the middle panel has a 5/16" hole and the upper panel has a 3/8" hole.*

- Lap joint/stitch welds—This procedure is used in sectioning and full panel replacement. In this type of joint, the replacement panel can be on the top or bottom. The edge of the top panel is welded to the bottom panel with 3/4" stitch welds to form a continuous weld. The stitch weld sequence is shown in **Figure 17-13**. Stitch welding lessens the buildup of heat, preventing warpage.
- Lap joint/spot welds—A squeeze-type resistance spot welder (STRSW) can duplicate factory spot welds in strength and appearance. Lap joints are the only type of joints that can be welded with a STRSW. **Figure 17-14** shows a STRSW in use on a rocker panel. This type of welding is much faster than using MIG plug welds. The STRSW welder must be able to reach both sides of the joint. This setup could also be used on a radiator support. Adjusting the length of the U-shaped clamp allows the welder to be used on shaped panels that require greater reach, such as rear body panels and the rear of pickup truck cabs. Adhesive applied to the mating surfaces of the lap joint prior to welding duplicates factory adhesive bonding.

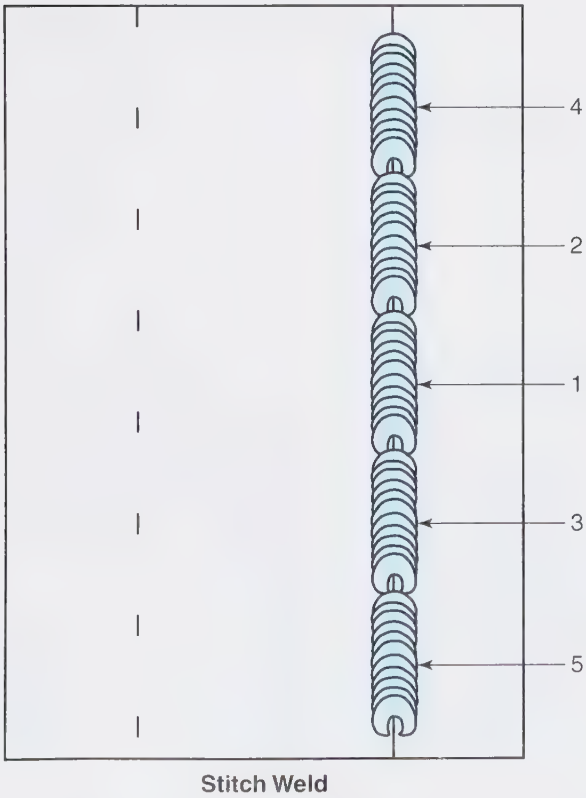


Figure 17-13. *A series of stitch welds make a continuous weld with minimal heating of the panels.*

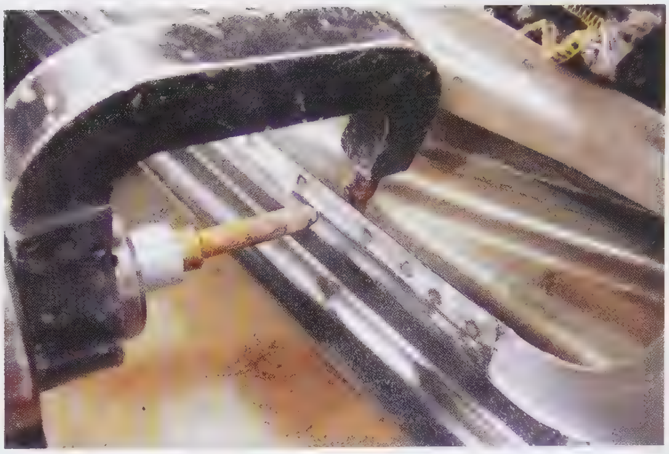


Figure 17-14. *A STRSW makes a neat spot weld. A row of welds is made first and then a weld is put in between the first set of welds.*

- Offset butt joint/stitch welds—**Figure 17-15**. This procedure is used in sectioning. Many structural parts consist of two or more panels that are welded together. When a structural part of this design is replaced, an offset butt joint can be used. In a butt joint, two panel edges are welded together. Offset means that the location of the joints is staggered. In this application, the joint for the inner panel is not directly across from that of the outer panel joint. The butt joints are stitch welded. Butt joint welding requires considerable skill.
- Offset lap joint/plug welds and continuous welds—This joint is used to section hydroformed aluminum full-frame rails the shape or angle of which may not allow an insert. Make 3" (75 mm) long cuts in opposite corners of the existing rail. Use tools that have not been contaminated with steel. Steel particles on cutting wheels or saw blades will cause corrosion problems on aluminum. Slide the replacement rail inside the existing rail for a test fit. The offset of the replacement rail inside the existing rail can be as much as 4" (100 mm). When the fit has been verified by measurements, the replacement rail is removed and plug weld holes are drilled into the replacement rail and the existing rail.

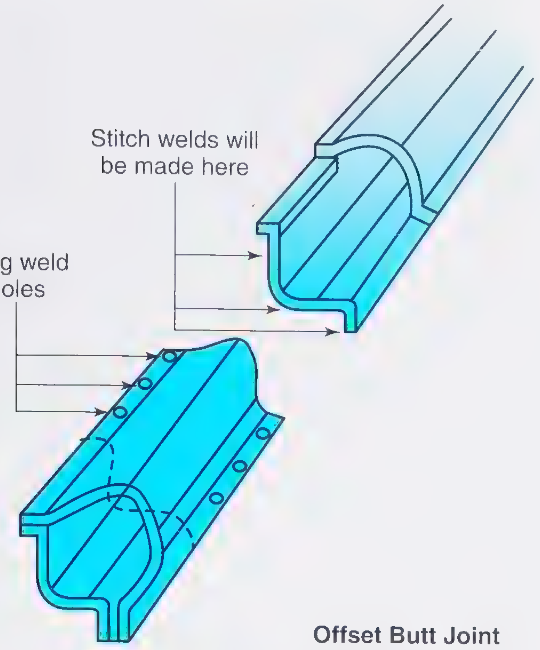


Figure 17-15. *The offset butt joint requires both plug and stitch welds.*

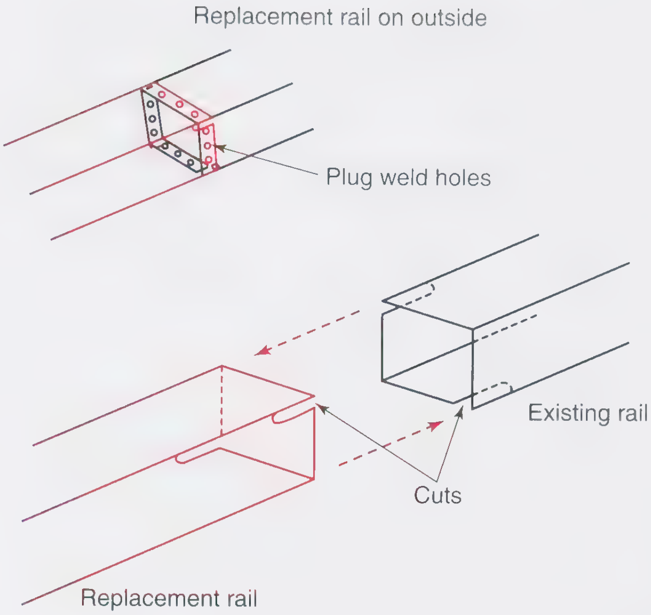


Figure 17-16. *In the offset lap joint, part of the replacement rail slides inside the existing rail and the rest remains outside the existing rail.*

See **Figure 17-16**. One-half of the plug weld holes are made in the replacement rail and one-half are made in the existing rail. The rails are prepped for plug welds and a continuous MIG weld at the end of the existing and replacement rails. Remove the oxide layer on the aluminum with a stainless steel brush before welding. The rails are assembled; then the fit and positioning of the replacement rail is again verified by measuring. The welds should be made with a pulse MIG welder using 0.035"-diameter 5356 alloy wire and 100% argon gas. Plug welds are made first, followed by continuous welds. The continuous weld should be made as a series of 2" long stitch welds. Allow the weld area to cool for 2 minutes for every 4" or 2 minutes of welding.

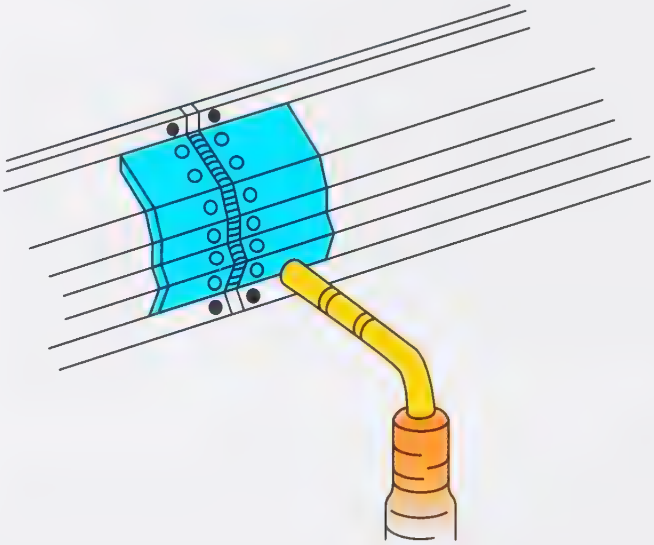


Figure 17-17. *A butt joint with an insert requires both plug and continuous welds.*

Butt joint with insert/plug and stitch welds—This procedure is used in sectioning. The insert serves as a backer for the weld. See **Figure 17-17**. This joint is easier to weld than a simple butt joint. The insert is made from leftover pieces of the replacement part. An insert for a rocker panel should be 4" (100 mm) wide, while an insert for an A-pillar or center pillar should be 2" (50 mm) wide. Trimming cuts are made on the insert to allow it to fit inside the other parts. Plug weld holes are drilled in both the replacement part and the original part. The insert is plug welded to the original part. The replacement part is installed by sliding it on the insert. A butt weld gap equal to one-and-a-half times the thickness of the panel should be left between the original panel and the replacement panel. When the alignment is correct, the replacement panel is plug welded to the insert. Then stitch welds are used at the butt joint to form a continuous joint.

Full-frame butt joint and backer plate/continuous weld—This procedure is used in sectioning. On full-frame vehicles, if the frame is cracked or sectioned, a backer plate can be used as reinforcement in the weld area. On a C-channel frame, the C-shaped backer is the same thickness and steel type as the frame. The backer should be at least 6" (150 mm) long. The backer plate is inserted in the inside of the C-channel frame and held in place with clamps. Then the butt joint is welded on the outside. To finish the procedure, backer plate edges are welded to the frame. See **Figure 17-18**.

If the structural component is aluminum, at least one vehicle manufacturer requires pulse MIG welding. The existing frame rail is cut and beveled to a 60° angle with tools used exclusively for aluminum. The full-frame replacement rail is pre-sleeved for the butt joint with an insert. A gap the same width as the thickness of the rail is set between the replacement rail and the existing rail. Remove the oxide layer on the aluminum with a stainless steel brush. The gap is welded in two passes with 2" long stitch welds using 0.035"-diameter 5356 alloy wire with 100% argon gas. Allow the weld area to cool for 2 minutes for every 4" or 2 minutes of welding.

Bond

Laminated steel components cannot be MIG welded, although some manufacturers may allow STRSW in certain component replacement situations. If no welding of any type is allowed, one manufacturer recommends a bonding and riveting procedure. The procedure for bonding and riveting a replacement component to a vehicle component is as follows:

1. Temporarily install the replacement component on the vehicle and measure to verify the proper location of the replacement component.
2. Drill 17/64"-diameter (7 mm) holes for rivets in the replacement component and in the vehicle component in the same locations that the factory spot welds were found on the damaged component.
3. Strip to bare metal all areas where adhesive will be applied. Do not damage or reduce the thickness of the metal while removing the paint.
4. Apply a 1/8"–1/4" (3–6 mm) wide bead of metal bonding adhesive to the all surfaces that will be bonded. Spread the adhesive with a brush to make sure all bare metal is covered.
5. Fit the replacement component into place. If it must be repositioned, do not separate the components. Instead, slide one against the other.
6. Measure to verify that the replacement component is in the proper place.
7. Install 11/32" (9 mm) rivets into the drilled holes.
8. Remove excess adhesive.

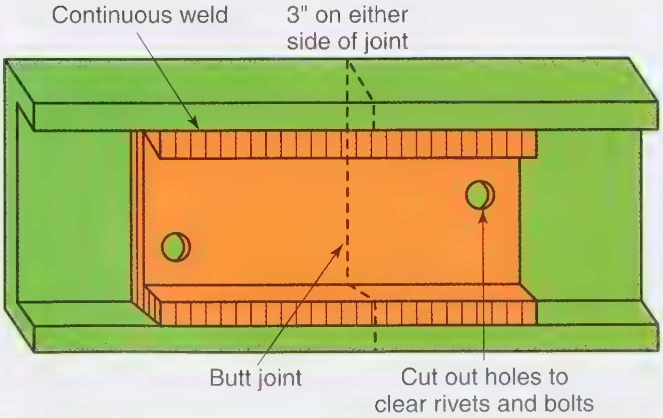

Continuous weld
3" on either side of joint
Butt joint
Cut out holes to clear rivets and bolts

Figure 17-18. *Backer plate is continuously welded to the frame.*

Rustproof and Paint

A weld will rust rapidly if it is not properly treated. Proper rustproofing will protect the vehicle from corrosion. Begin by grinding MIG plug welds and continuous welds to remove any pores or pits. Plug welds can be ground flush without loss of strength. Grind only on the weld, not on the surrounding metal. Clean off weld scale with a sandblaster, wire wheel, or nylon abrasive disk. STRSW welds can be sanded with 80-, 180-, and 320-grit sandpaper to smooth them before primer application. The goal is to clean up the surface of the weld so the epoxy primer will adhere to it properly. The back side of the weld must also be cleaned. After welding, any exposed weld-through primer should be removed by sanding or wiping with lacquer thinner, as it will not allow the epoxy primer to adhere to the metal. In enclosed areas, such as a lower frame rail, use a long-handled brush to remove weld scale. If the joint is unreachable with a brush, direct a stream of compressed air inside the rail. This will remove some scale. Spray two coats of ***epoxy primer*** on all treated weld areas. Once the epoxy primer has cured, apply ***seam sealer*** to joint edges as shown in **Figure 17-19**. Then apply base coat and clear coat as needed. On enclosed surfaces, spray on a ***wax-based rustproofing*** material.

Replace Foam

Foam may be found inside rocker panels and pillars on some vehicles. After the replacement part is welded in and rustproofing has been applied, the foam should be replaced. Some replacement structural parts may already contain foam.

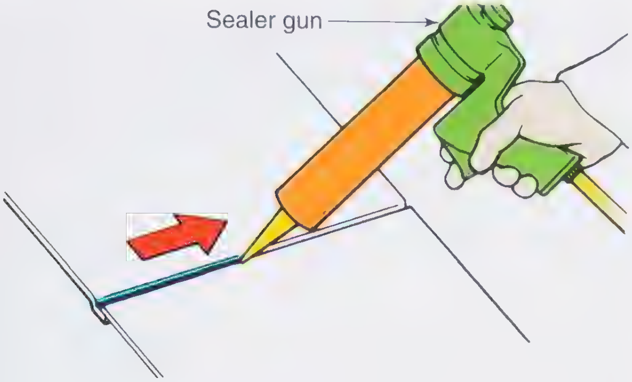


Figure 17-19. *After applying epoxy primer, apply seam sealer to the joint. The seam sealer prevents a pocket from forming between panels that could trap contaminants and cause rust. (Toyota)*

Two-part ***low-density foam*** starts out as semi-liquid that is sprayed or pumped into the cavity. The foam expands and changes to a solid as it cures. The expansion rate may be as much as ten times. Excess foam will squeeze out through the nearest hole. Low-density foam is flexible enough that it will not change the shape of a panel if too much is applied. After the foam cures, any drain holes that have been clogged should be cleared.

Some parts contain epoxy or polyurethane ***high-density foam*** designed to make the panels more rigid. The foam is dispensed as a two-part semi-liquid. The two parts mix in the tube as they are dispensed. When the semi-liquid foam is installed inside a cavity, it is strong enough to bend weak panels as it expands and cures. One type of foam expands instantly into a solid; another type of foam has delayed expansion. The volume of the cavity to be filled must be roughly estimated. Pumping too much high-density foam into the cavity may create overexpansion problems and even cause welded panels to separate.

Foam installation instructions from the OEM may be included with the replacement structural part. The procedure may involve pumping a predetermined volume of foam into the cavity, waiting for expansion to be completed, and then pumping in more foam if required. Also, dams may be supplied with the part to aid in placing the foam in the proper location. Delayed expansion foams allow the semi-liquid, uncured foam to run down into all areas of the panel before expansion occurs.

Reassemble

After repairs are made, the vehicle must be reassembled. Reassembly includes the installation or replacement of nonstructural parts such as a bumper cover, bumper reinforcement, fender, and hood, as well as mechanical parts such as the A/C condenser, radiator, and electric fan.

Replacement Part Sources

Replacement parts can be new or salvaged. New parts, such as radiator supports, upper and lower frame rails, aprons, unisides, rocker panels, center pillars, and rear frame rails, are available individually. See **Figure 17-20**. A ***salvaged part*** is a used part taken from a salvaged vehicle. Salvaged parts are usually sold as part of an assembly, **Figure 17-21**.

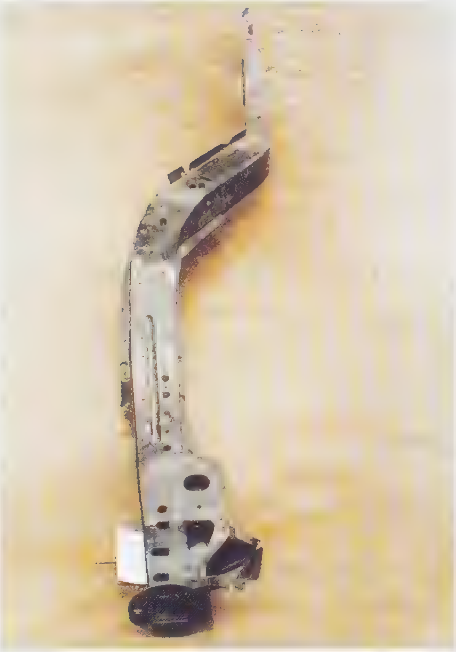


Figure 17-20. *OEM parts, such as this front lower frame unirail, are often supplied as a single part rather than as an assembly.*

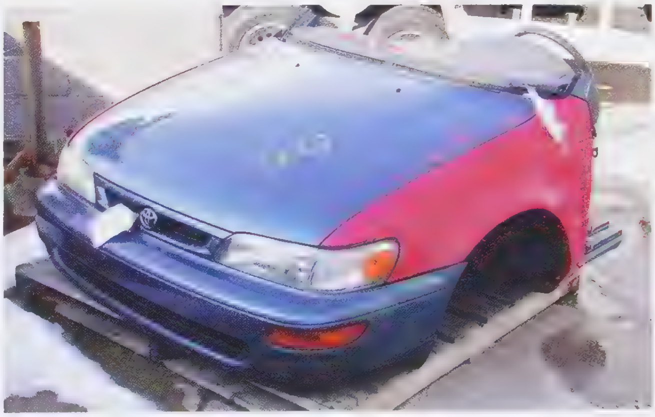


Figure 17-21. *Salvaged parts are supplied as an assembly. This used front section includes the radiator support, upper and lower frame rails, aprons, shock towers, and cowl.*

WORKING GREEN

It is good practice to install salvaged parts whenever possible. Not only will using salvaged parts reduce repair costs, but it also helps minimize the number of automotive parts that end up in landfills and eliminates the environmental effects that result from the manufacture of new parts.

Salvaged assemblies should be cut off at the salvage yard with a saw, cut-off wheel, or plasma cutter. If a cutting torch is used on the metal at the salvage yard, at least 2" of additional material around the cut should be removed at the collision repair shop before the part is used. The reason for this is that the heat of the cutting torch used at the salvage yard may have weakened the steel. Cutting off the area around the torch cut will help prevent the use of weakened steel.

The use of salvaged parts will reduce repair costs, so salvaged parts are often specified for repairs. The common salvaged assemblies are the front section, side section, and rear section. The entire assembly can be installed, or a portion of the assembly can be used. With a salvaged assembly, there is often less welding during the repair because some of the replacement parts are already welded together.

Front Section

A ***front section***, or ***front clip***, is shown in **Figure 17-22**. The front section consists of all the body parts ahead of the front seat. Some parts, such as the radiator support, can be drilled out and used by itself. If two or more pieces that are welded together, such as the radiator support and the lower front frame rail, are needed, they should not be separated. Instead they should be installed as a unit.

Side Section

A ***side section***, or ***side clip***, can consist of the entire side of a vehicle. Parts of the side section include the upper and lower frame rails, front shock tower, A-pillar, rocker panel, center pillar, quarter panel, rear shock tower, and rear frame rail. The body shop can cut out and use only the parts that are needed. **Figure 17-23** shows a short side clip that does not include all of the A-pillar. This clip will be sectioned at the A-pillar, upper C-pillar, and rear rocker panel. A long side clip includes the upper frame rail, apron, shock tower, and lower frame rail; all of the rocker panel; all of the A-pillar, including the A-pillar portion of the windshield opening; all of the B-pillar; and the entire C-pillar, including the side of the back glass opening and the entire quarter panel.

Rear Section

A ***rear section*** consists of all body parts from the rear doors to the rear end. This would include a portion of the rocker panels, quarter panels, rear shock towers, trunk floor, rear frame rails, and rear body panel. **Figure 17-24A** shows a rear section. The roof is not needed in the repair plan. The quarter panels, trunk floor, and rear body panel will be separated from the rear frame rails, so only part of this rear section will be used in the repair. Any of these parts can be removed for separate use.

Rear Section and Roof

A ***rear section and roof***, or ***rear clip top***, is shown in **Figure 17-24B**. This assembly is used to ***clip*** a vehicle. In clipping, a rear-damaged vehicle is cut at the windshield pillars and across the floor ahead of the front seat.

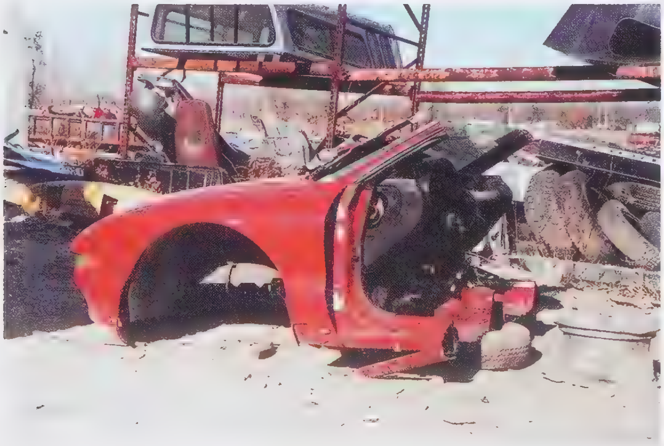


Figure 17-22. *The front section includes all the parts ahead of the front seat.*

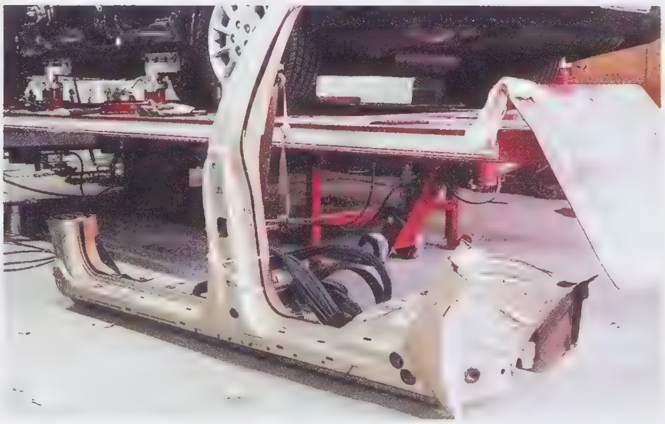


Figure 17-23. *This side section does not include the quarter panel or most of the A-pillar because the repair did not require these parts.*

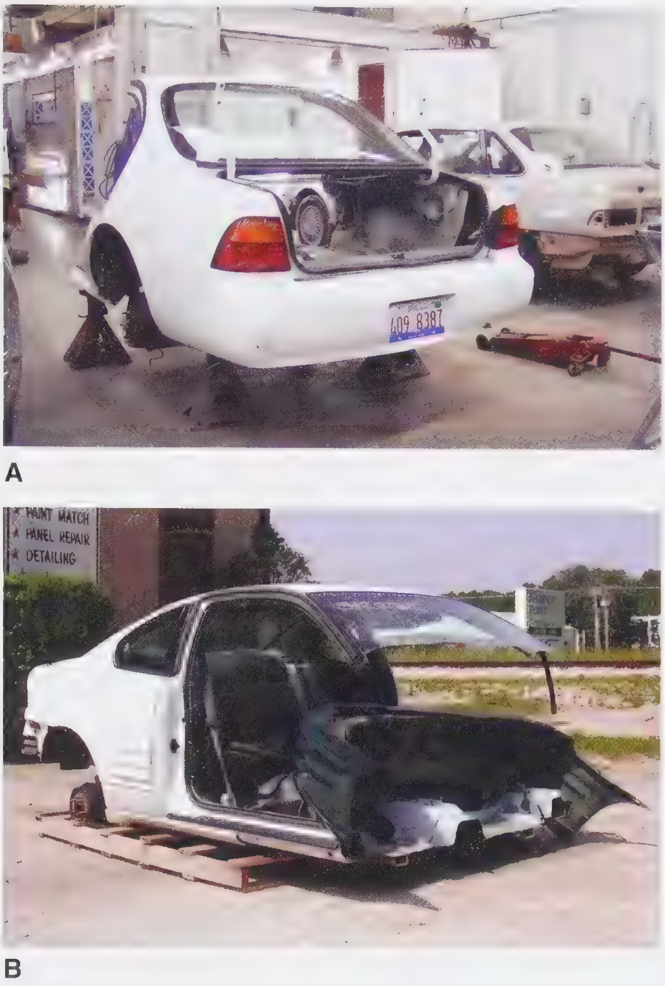


Figure 17-24. *A—The rear section includes all parts to the rear of the backseat. This repair did not require the deck lid so the rear section does not include it. B—The rear section and roof assembly, or rear clip top, includes everything to the rear of the front seats.*

See **Figure 17-25**. This separates the damaged vehicle into two halves, the undamaged front section and the damaged rear section. A salvaged rear section and roof are welded to the undamaged front section. The individual parts—quarter panel, rear body panel, rear frame rail, trunk floor, rear shock tower, rocker panel, center pillar, and roof—can be removed from the rear section.

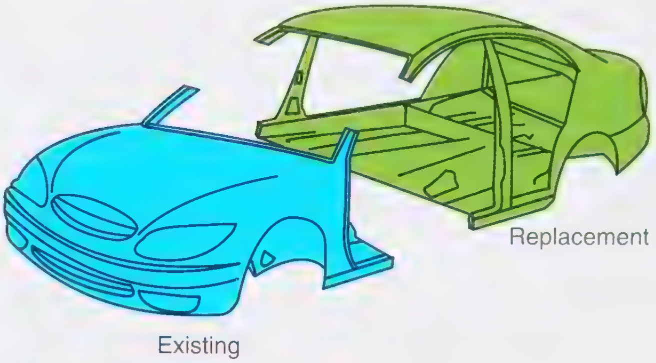


Figure 17-25. *A rear-hit vehicle can be repaired with a full-body section. The damaged vehicle is cut at the windshield pillars and across the floor. The replacement full-body section is welded in place.*

Replacing Structural Unibody Components

The following sections detail the replacement procedures for common structural unibody components. The structural integrity of a repaired unibody vehicle is dependent on all the relatively thin structural panels retaining their designed strength. The strength of the unibody structural panels can be compromised by failing to straighten the damaged unibody back to specified dimensions, by not replacing kinked structural parts, by sectioning in the wrong place, by inadequate welding, or by failure to restore corrosion protection. Do not compromise the strength of the vehicle; follow the manufacturer's replacement recommendations carefully. The installation of both new and used parts is presented in each section.

Structural components are welded together and are often three or more panels thick. A structural component that is under one or more layers of metal may need to be removed without damaging the upper panel or the underlying panel. Careful spot weld drilling is required to save the panels that will be reused.

Radiator Support

Radiator supports can be made of steel or plastic. Some steel radiator supports bolt in place. Others are welded in place. Some steel radiator supports are a combination of welded and bolted parts. Plastic radiator supports are bolted or riveted in place. Bolted structural component replacement is similar to bolted nonstructural component replacement. Simply measure to make sure the part is in the correct place and then install the fasteners. If a torque specification is available, follow the specification when installing the fasteners.

Replacement of a riveted radiator support requires that the factory-installed rivets be drilled out with a drill bit that is slightly larger in diameter than the center hole in the rivet. Pop rivets are used to secure the replacement radiator support.

Figure 17-26 shows a breakdown of parts that make up a steel radiator support. Radiator supports for some vehicles are shipped as an assembly. If the radiator support is supplied in individual pieces, only the damaged portions need to be replaced.

To replace a steel radiator support that is welded in place, begin by removing the headlights, front bumper, grille, fenders, and fan assembly. Drain and remove the radiator. Evacuate the air conditioning system and remove the condenser. Remove any other components that may impede radiator support replacement.

Determine if any related components, such as the lower and upper front frame rails, apron, and shock towers, have been moved or damaged. If necessary, make pulls to bring the parts attached to the radiator support into alignment. Take measurements to verify the pull. If necessary, perform additional pulls until the support is in alignment.

Decide what portion of the radiator support will be replaced. If the replacement radiator support is supplied as an assembly, replace the entire support.

Spot welds that impede/interfere with the removal of damaged parts are located and drilled out. Remove the nuggets that remain after drilling out the spot welds. Pretreat the existing and replacement parts. Punch plug weld holes as needed. Sand the replacement part and the existing part to bare metal in the weld areas. Apply weld-through primer as needed.

Install the radiator support on the vehicle. **Figure 17-27** shows a partial replacement of the radiator support with the parts supplied as several pieces rather than as an assembly. Measure carefully to make sure it is properly aligned. Then clamp the support in position and weld it in place. To minimize heat buildup, use stitch welds or skip welds.

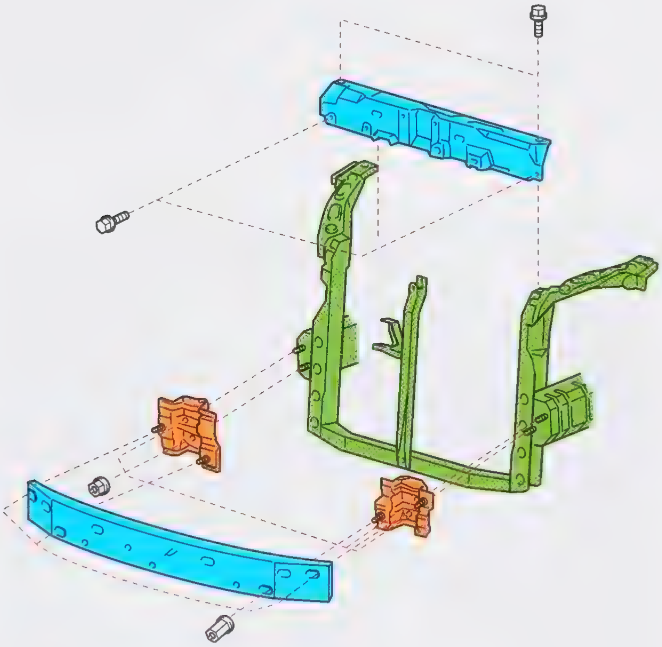


Figure 17-26. *This radiator support has an upper tie bar and baffles. Some radiator supports also have a front cross member. (Toyota)*

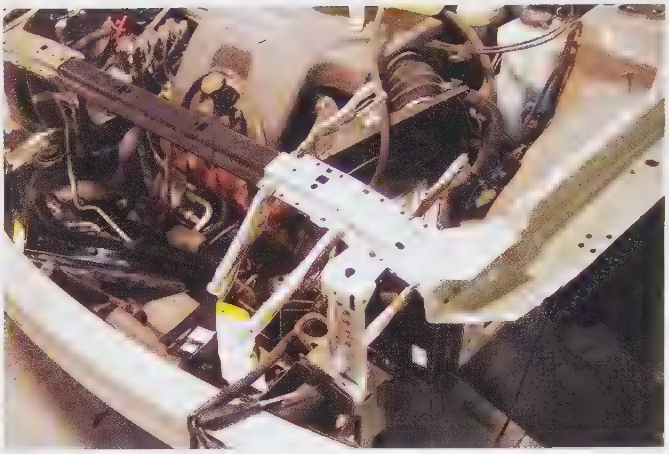


Figure 17-27. *This radiator support is supplied as several pieces. Notice the clamps and plug weld holes.*

The radiator support and adjacent panels must be cleaned and the welds dressed before sanding. After sanding, the radiator support should be sprayed with epoxy primer. Then the topcoat can be applied. After the topcoat has been applied, the frame rails can be rustproofed.

Finally, reassemble the mechanical and nonstructural parts that were removed from the vehicle. Install mechanical components first. Then install the fenders, headlights, grille, and front bumper.

One type of welded-in-place radiator support requires that the upper rails, which overlap the radiator support, be cut at specified locations to allow the removal of the radiator support. The cut locations are indicated on the upper rails with die marks. The new radiator support includes predrilled corner splice panels. After welding in the replacement radiator support, the corner splice panels can be welded to connect the radiator support to the upper frame rails.

If a used radiator support will be installed, the installation steps are essentially the same as those for a new radiator support except that a used radiator support requires more prep work than a new support. The salvage yard will remove the radiator support from the salvage vehicle by cutting the upper frame rails, aprons, and lower frame rails. The used radiator support must be separated from the parts that will not be installed by drilling out the spot welds. Once these parts are removed, the used radiator support replacement steps are the same as those for a new radiator support.

Apron

The apron is welded to the shock tower, upper frame rail, lower frame rail, and possibly, the radiator support. The apron fills the space between these parts and adds little to the structural strength of the vehicle. An apron is usually replaced along with other parts, such as the radiator support or the upper frame rail. As with other structural component procedures, remove bolt-on parts that block access. These parts include the fender, headlight, radiator, battery, and coolant tank. Usually, the apron is not measured directly when checking alignment. Instead, the component the apron is attached to, such as the radiator support, is measured. Straighten the apron, and whatever it is attached to, by pulling. Measure again to verify that all components have been realigned properly. Decide which panels will be replaced and how to make the joints.

Always replace the entire apron. Aprons should never be spliced. Drill out the spot welds and remove the damaged panel. Clean the existing panels that will be welded with wax-and-grease remover. Grind down any nuggets and sand to bare metal any areas that will be welded.

Punch or drill plug weld holes in the replacement part. If possible, plan to make the welds on the nonappearance side of the part. By making the plug weld on the side of the part that does not show, it will be much easier to finish the weld. See **Figure 17-28**.

Apply weld-through primer to the bare metal surfaces that will be welded. Install the part and check alignment. Hold the replacement part in alignment with sheet metal screws or clamps. MIG plug weld the plug weld holes. Dress the welds and remove any weld scale or blistered paint. Apply epoxy primer, followed with seam sealer and topcoat. Reassemble the vehicle.

If a used apron is installed, it will probably involve the replacement of the radiator support and/or the upper frame rail as well. Try to install the used parts as a unit rather than individually. Remove any unnecessary portions of the used radiator support, apron, and upper frame rail by drilling out the spot welds. Leave the factory spot welds that connect the radiator support, apron and upper rail in place.

Shock Tower

Front or rear shock tower replacement, **Figure 17-29**, is usually done as part of other operations because other structural parts will be damaged before the tower is damaged. The position of the shock tower will determine steering geometry. Therefore, careful measurement is critical.

Begin shock tower replacement by removing the outer sheet metal (fender, hood, front bumper, etc.) and any suspension or mechanical parts that will prevent shock tower removal. Use an upper body gauge to measure the exact location of the shock tower. If necessary, align the shock tower and all attaching parts by pulling. After pulling, measure again to confirm that the shock tower and attaching parts are in the right position.

Never section a shock tower. Instead, replace the entire tower. Remove the damaged shock tower by drilling out the spot welds holding the tower in place. Access to some spot welds may be limited, as overlapping of metal may be present. If the layer to be removed is between two other layers, drill through all three layers if the area can be welded from both sides. If not, drill through the upper two layers only.

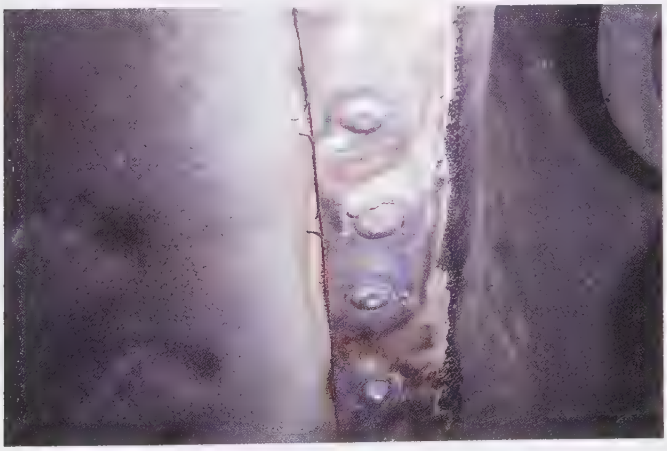


Figure 17-28. *This apron was welded from inside the wheel house. Nonappearance side of this panel can be cleaned and primed without grinding the plug welds.*

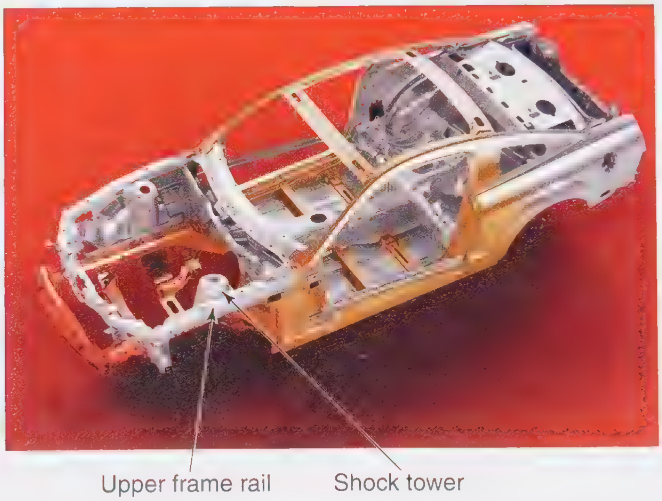


Figure 17-29. *Replacement of the shock tower requires the removal of many parts, including the drive train.*

Punch plug weld holes in the replacement part as needed. Sand weld areas to the bare metal. Apply weld-through primer. Dress the weld nuggets on the original part. Punch plug weld holes as needed and sand weld areas to bare metal. Apply weld-through primer.

Position the replacement tower on the vehicle. Measure carefully to make sure the part is properly aligned. When fit up is complete, weld the tower in place. Stitch welds or skip welds will minimize heat buildup.

After the tower has been welded in place, dress the welds and clean the repair area. Scuff sand and spray epoxy primer on the shock tower and on the inside frame rails where welding burned the paint. Finally, apply topcoat and rustproofing materials. Reassemble the mechanical and nonstructural parts.

If a used shock tower is installed, it will probably include replacement of the radiator support, apron, lower frame rail, and upper frame rail. Replacement of this portion of the vehicle is called a left or right 3/4 front, depending on which shock tower is replaced. When replacing this much of the vehicle, used parts may be easier to install because the factory welds connecting the radiator support, apron, shock tower, upper frame rail, and lower frame rail can be left intact. A used front section will probably be supplied from a salvage yard. The front section should include the entire lower frame rail because the lower frame rail will not be spliced (the entire rail will be installed). A vehicle that has been hit this hard will probably have cowl and center section floor damage. Straighten all damage to the cowl and floor before removing the damaged structural components. Prepare the used assembly by removing unneeded components. If a left 3/4 front is installed, welds are made at the right side of the radiator support, at the cowl (for the shock tower and upper frame rail), and on the floor of the center section of the vehicle (for the lower frame rail).

Upper Frame Rail

The upper frame rail may be supplied as an assembly that includes the apron or just the rail. The rail may also be supplied in pieces. The upper frame rail parts are shown in **Figure 17-30**. The outer portion of the upper frame rail is easily accessible on most vehicles. It should not be sectioned. The inner portion of the upper rail may be under several layers of metal at the cowl. The inner rail may need to be sectioned. If this is the case, remove the outer upper frame rail. Section the inner rail and then reinstall the outer rail.

Begin upper frame rail replacement by removing the hood, fender, and other outer parts as needed. Take measurements to locate misalignment in the frame rail or related parts. If necessary, pull the rail and attaching parts into alignment. Then, measure again to verify that all parts are in the correct location.

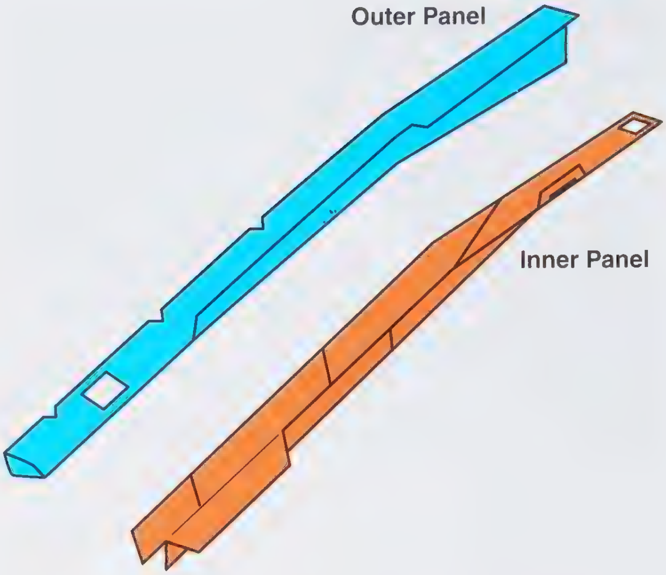


Figure 17-30. *The upper frame rail consists of inner and outer panels.*

Obtain sectioning information and decide if the inner rail will be sectioned. If so, choose a location. The section joint is often a lap joint. Drill out spot welds and cut continuous welds holding the rail in place. If the rail will be sectioned, rough cut the original rail. Remove the damaged frame rail from the vehicle.

Prepare the replacement part for installation. If the frame rail is to be sectioned, measure and cut the section joint. Punch plug weld holes in the replacement part as needed. Sand the weld areas to the bare metal and spray on weld-through primer.

Pretreat the original parts. Dress the weld nuggets. Measure and cut the section joint if necessary. Punch plug weld holes in the original part as needed. Sand the weld areas to bare metal, and apply weld-through primer.

Fit up the replacement rail. Install the fender and hood to ensure proper alignment. When everything is aligned properly, weld the replacement frame rail in place. Weld the lap joint first. Then make plug welds.

Dress the welds and clean the panel. Scuff sand the panel, spray the epoxy primer, and apply the topcoat. Finally, apply the rustproofing.

If a used upper rail is installed, it is usually part of an assembly, such as the radiator support, apron, and upper rail assembly. A high hit that damages the radiator support, both aprons, and both upper rails can be repaired with a used assembly. The entire outer upper rails, aprons, and radiator support are installed. Then the inner upper rails are spliced. The factory welds connecting the radiator support, aprons, and upper rails are left intact.

Lower Front Frame Rail

Lower front frame rails can span the distance from the radiator support to a point under the passenger compartment. A major structural part, the lower front frame rail has many other panels welded to it. For this reason, a lower front frame rail is often sectioned if the damage is ahead of the section joint location.

Begin by removing the front bumper, grille, fender, and all mechanical parts necessary to access the lower front frame rail. Measure the position of the rail and attached components. Align the lower frame rail and attached components by pulling. Measure to verify that the rail is straight.

Obtain the appropriate sectioning location information and determine if all the damage is within the section area. Decide whether sectioning is feasible. There are two types of joints used in this type of repair: a butt joint with an insert and a lap joint. In a butt joint with an insert, the original rail and the replacement rail are cut to leave an expansion gap between the rails that is 1 1/2 times the thickness of the rail. The length of the insert should be the same as the diagonal width of the frame rail. Calculate the diagonal width by measuring the width of the undamaged rail from the upper left corner to the lower right corner. If a lap joint will be used, the replacement rail is cut about 1"– 1 1/2" longer than the original rail. The longer length of the replacement rail allows it to slip inside the original rail. One-inch slits are cut in each corner of the replacement rail, and if a flange is present, a notch is cut out of it. The slits allow the edges of the replacement rail to be turned in so the end of the replacement rail is just slightly smaller than the original rail. This slight change in size lets the replacement rail slip inside the original rail. The sectioning procedures supplied by the manufacturer will specify the type of joint and the size of the insert or overlap. Drill out spot welds from attaching panels, such as the apron and radiator support. Rough cut the rail and remove it.

Templates are available for some types of vehicles. Instead of transferring measurements, the paper template is used as a vehicle-specific guide for cutting. See **Figure 17-31**. It is folded so it will fit on the corners of the frame rail. The template has reference holes so it can be aligned to match holes in the frame rail. Both the replacement and original rail are cut using templates. If templates are not available, measurements can be used to locate the cut line. Inserts can be cut from the unused portion of the replacement rail. Punch plug weld holes in the replacement part, remove the e-coat from the weld areas, and spray on weld-through primer.

Final cut the original part using a template or measurements. Punch plug weld holes as needed. Sand the weld areas to bare metal and apply the weld-through primer. Plug weld the insert to the original frame rail. Position, measure, align, and install the replacement frame rail. Make the plug welds on the replacement rail. Then make the stitch welds at the section joint.

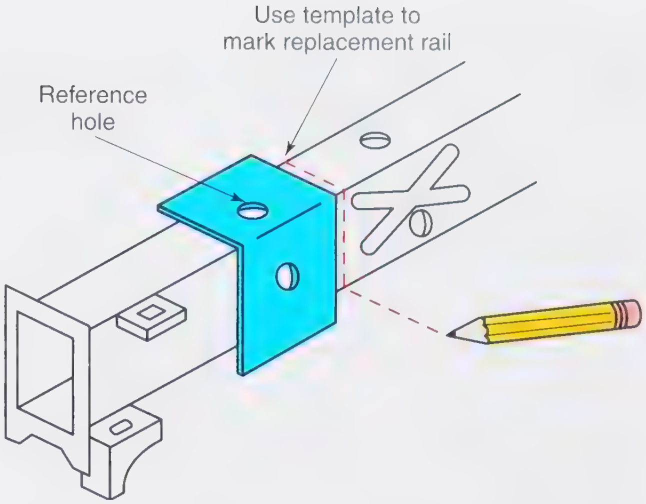


Figure 17-31. *The template indicates where the cuts should be made for front lower frame rail sectioning.*

Dress the welds. Remove as much weld scale from the inside of the rail as possible. Clean and scuff sand the panel. Spray on epoxy primer and topcoat. Finally, apply the rustproofing and reinstall or replace nonstructural and mechanical parts.

If the entire lower frame rail will be replaced, remove the drive train. Then remove front seats and roll back the carpet. Locate and drill out the spot welds that join the lower frame rail to the floor. The frame rail will also have spot welds that join it to the cowl, shock tower, apron, and radiator support. Locate and drill these out also. Pretreat the components to be welded.

Install the replacement lower frame rail with sheet metal screws and clamps. Carefully measure to determine that the replacement rail is in the correct location. Weld the floor to the rail from inside the vehicle.

If a used lower frame rail is installed, it is usually part of an assembly that includes the radiator support. If a vehicle is hit low and the radiator support and lower frame rail are not repairable, a used radiator support and lower rail can be installed. The lower rail is spliced in front of the shock tower. Do not drill out the factory spot welds connecting the radiator support to the lower frame rail. If both lower rails are damaged, both rails can be spliced with a used assembly.

A-pillar

An A-pillar and related parts are shown in **Figure 17-32**. The A-pillar is part of the cowl and is one of the strongest parts of a unibody vehicle. An A-pillar consists of inner and outer panels, as well as internal reinforcements.

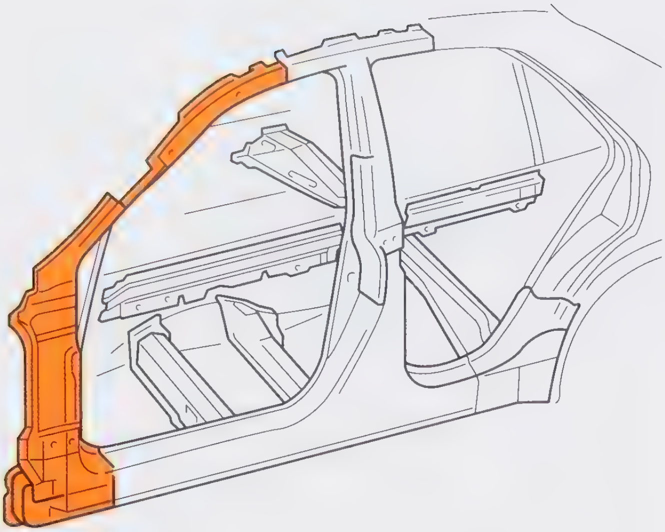


Figure 17-32. *This diagram shows the outer A-pillar. (Toyota)*

All these components are spot welded and continuously welded together in a lap joint. Notice that the A-pillar extends to the roof. The portion of the A-pillar that supports the windshield is called the windshield pillar.

A side hit on the A-pillar can cause considerable hidden damage. Be sure to find all the damage before cutting any parts. If the damage extends into the passenger compartment, remove the dash and windshield, as well as the door and fender. Look for buckles in the cowl. If only the outer portion of the A-pillar is damaged, dash removal may not be necessary.

If the upper portion of the A-pillar will be installed, the outer upper frame rail must be removed from most vehicles because it blocks access to the spot welds that hold the A-pillar to the cowl. Drill out the spot welds on the outer upper rail but do not damage the underlying panel. If the damage includes the windshield pillar, the windshield will need to be removed. Electrical wires or foam may be located inside the windshield pillar.

Take width measurements of the passenger's compartment, as well as underbody measurements. If necessary, pull the cowl into alignment. Take additional measurements to verify that the cowl is in the right location.

Decide which A-pillar parts must be replaced. If the inner panel of the A-pillar is kinked, the outer panel and reinforcements, as well as the inner panel, must be replaced or sectioned. This method usually involves sectioning the inner panel and replacing the reinforcements and outer panel.

If only the outer panel is kinked and the inner panel is bent but not kinked, the outer panel and the reinforcement should be replaced, but the inner panel can be straightened. If only the outer panel is bent and the inner panel is not damaged, pulls on the outer panel may straighten the outer panel. Check the vehicle manufacturer's recommendations for splice locations. One manufacturer recommends that the splice be made in the straight portions of the windshield pillar and rocker panel. Some manufacturers allow a splice joint between the door hinge mounts or under the lower hinge mount. For some vehicles, the A-pillar is supplied as part of a uniside. The uniside, which includes the outer portions of the A-pillar, windshield pillar, rocker panel, B-pillar, quarter panel, and roof edge, must be cut so the needed portion of the uniside can be installed. Other vehicles have a door opening surround. The door opening surround includes the outer portions of the A-pillar, rocker panel, C-pillar, and roof edge. As with a uniside, the needed portion of the door surround is cut out.

The sectioning joint will usually be a butt joint with an insert on inner and outer components. If a reinforcement must be replaced, try to replace the entire reinforcement. If this is not possible due to accessibility problems, use a butt weld splice on the reinforcement. If the windshield pillar will be removed, support the roof as shown in **Figure 17-33** so the roof will not sag.

Pretreat the replacement part or parts. Cut the replacement parts and inserts as needed. If the components will be MIG welded, punch or drill holes for plug welds. Remove paint from surfaces that will be welded. Apply weld-through primer as needed.

Pretreat the original part and dress the weld nuggets. Measure and final cut the section joints. Sand all weld areas to bare metal and apply weld-through primer. Weld the inserts in place.

Fit up the replacement part or parts. These recommendations assume that the A-pillar is spliced in the windshield pillar and the rocker panel. If the splice is made between the door hinge mounts or under the lower hinge mount, the windshield is not involved in the replacement.

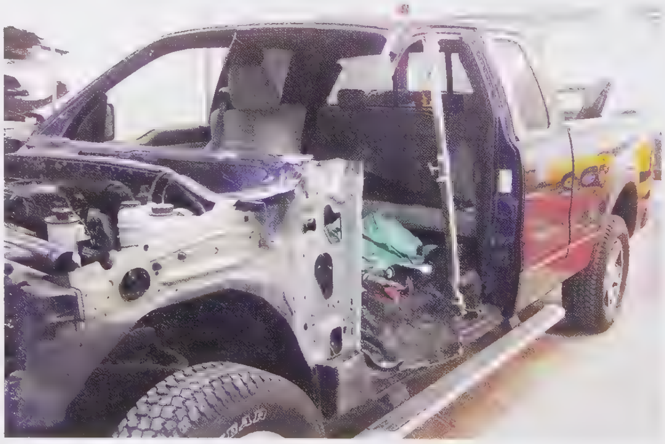


Figure 17-33. *Removing the A-pillar will cause the roof to sag. The support was installed before the A-pillar was removed.*

If the inner reinforcement and outer panels will be installed, position the parts and screw them together using sheet metal screws. Install the door and windshield or use a comparative laser to check the alignment. Adjust the panel location as needed.

Once everything is in the proper place, remove the outer panel and reinforcement. Then weld the inner panel in place. Make the plug welds to the insert first and then make skip welds on the butt joint. Weld the reinforcement next, followed by the outer panel.

Install the door and windshield or use a comparative laser to check alignment. Once the alignment has been verified, remove the outer panel and weld the reinforcement in place. Then weld the outer panel. If just the outer panel will be replaced, install the outer panel with sheet metal screws and check the alignment of the door and windshield. Adjust the position of the outer panel as needed for proper alignment. Weld the outer panel in place.

Dress the welds and clean the panel. Scuff sand and spray the epoxy primer inside and outside the pillar. Apply seam sealer and rustproofing as needed.

A used A-pillar can be installed. However, if the factory spot welds that attach the inner panel to the cowl are accessible only by removing the outer panel, the used assembly will need to be separated into inner and outer panels before installing. If only the outer panel is needed, carefully drill out the spot welds without damaging the outer panel.

Rocker Panel

Rocker panel parts are shown in **Figure 17-34**. A rocker panel can be sectioned as shown in **Figure 17-35**. The outer rocker panel may be part of a door opening or uniside. When the rocker panel is damaged, the center pillar is often damaged as well. The outer rocker panel can be replaced by itself, or the inner rocker panel and reinforcement can also be replaced. Check the manufacturer's recommendations to see if the reinforcement can be sectioned. Some vehicles may not have a reinforcement. See **Figure 17-36** for the sectioning procedure for two or three layers — the reinforcement and the outer rocker panel.

To begin rocker panel replacement, remove the doors. If the inner rocker panel will be replaced, remove the seats on that side of the vehicle and roll back the carpet. Measure the extent of the damage. Align the unibody by pulling and stress relieving. Measure again to confirm the location of structural parts. Obtain sectioning information and determine if sectioning is appropriate. If the inner rocker panel, reinforcement, and outer rocker panel will be sectioned, butt joints with inserts will be used on the inner and outer panels and a butt joint will be used on the reinforcement. If more than one reinforcement is present, both reinforcements will be butt welded. Use butt joints on reinforcements and a butt joint with an insert on the outer rocker panel if only the reinforcement and outer rocker panel will be replaced.

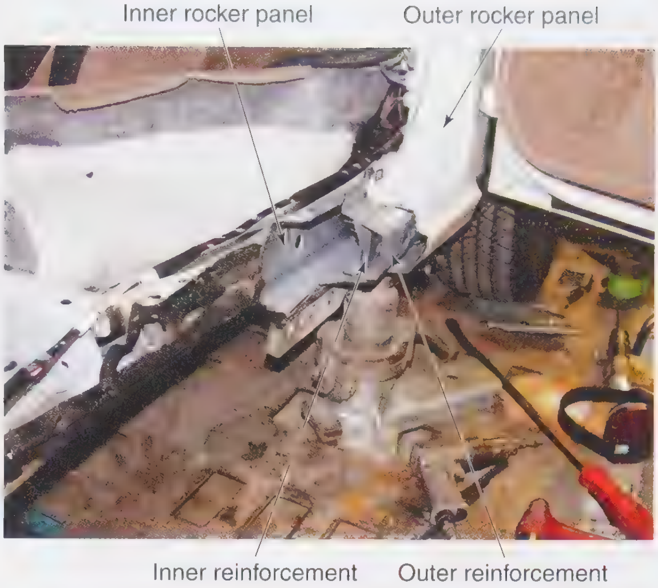


Figure 17-34. *The rocker panel consists of inner and outer panels and reinforcements.*

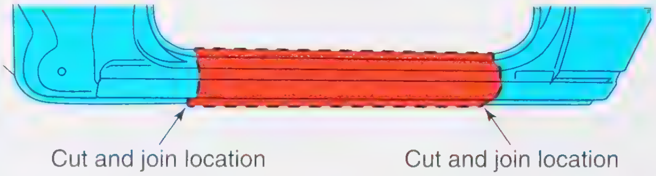


Figure 17-35. *In this example, the outer rocker panel is sectioned in the door opening. (Toyota)*

Rough cut the damaged rocker panel or panels and drill out the spot welds. Be sure to support the vehicle before cutting, as removing the rocker panel may weaken the floor causing a sag.

If the inner rocker panel, reinforcements, and outer rocker panel will be replaced, first rough cut the inner rocker panel. Dress the weld nuggets that remain after removing the inner rocker panel from the floor. Clean the floor edge and sand it to bare metal. Punch or drill the proper number of plug weld holes in the inner rocker panel flange that will weld to the floor. Position the replacement inner rocker panel on the rough cut original rocker panel. Use clamps or sheet metal screws on the inner rocker panel flange to hold the panel to the floor. Determine where the sectioning joints will be made and cut the replacement and original panels together. Cut out inserts from the unused parts of the replacement rocker panel. Drill or punch plug weld holes in the original and replacement inner rocker panels. Sand to bare metal all areas that will be welded. Apply weld-through primer to all bare-metal areas.

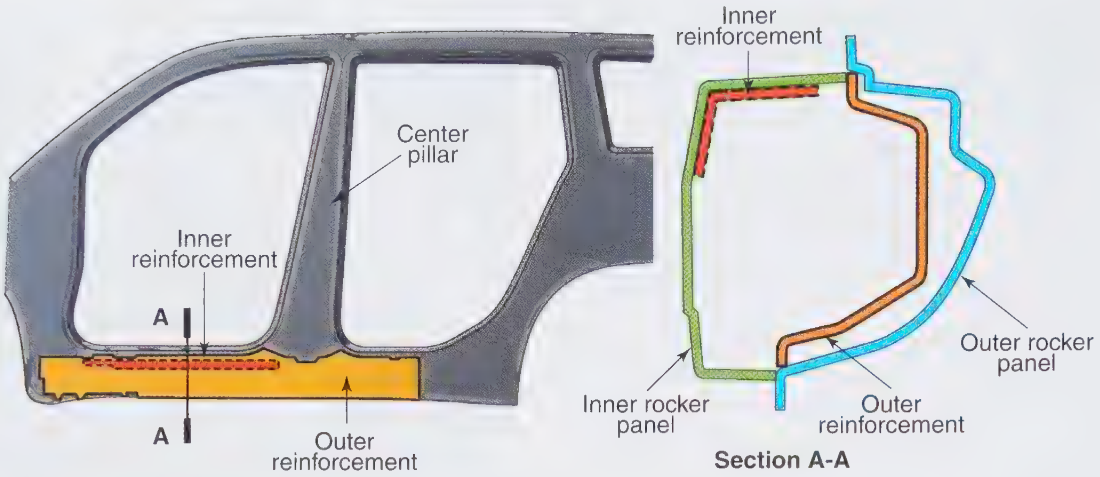


Figure 17-36. *Some manufacturers allow the rocker panel reinforcements to be sectioned in. (Toyota)*

Place the inserts on the inner rocker panel joints and secure them with sheet metal screws. Rough cut the reinforcement(s). Then, test fit and final cut the reinforcement or reinforcements. Rough cut and install the outer rocker panel. Final cut the replacement rocker panel and the original rocker panel.

Position the outer rocker panel on the vehicle and hold it in place with sheet metal screws. Install the doors and check the alignment. Reposition the outer rocker panel as needed.

Remove the outer rocker panel. Weld the inner rocker panel inserts to the original inner rocker panel. Weld the inner rocker panel plug weld holes first and then weld the butt joint. Grind the plug welds, remove the weld scale, and spray the bare metal with weld-through primer. Next, punch or drill plug weld holes in the reinforcements. Position and weld the reinforcements in place. After welding, grind the welds, remove the weld scale, and spray with weld-through primer. Cut the inserts from the leftover parts of the replacement outer rocker panel. Punch or drill plug weld holes in the upper and lower flanges of the outer rocker panel. Strip the weld areas to bare metal and apply weld-through primer. Weld the inserts to the original rocker panel with MIG plug welds. Install the replacement outer rocker panel and secure it with sheet metal screws. MIG weld the plug weld holes first and then weld the butt joint.

If only the outer rocker panel will be replaced, determine the section joint location on the replacement rocker panel. Cut out pieces of unused rocker panel for inserts. Punch plug weld holes in the replacement panel and sand all weld areas to bare metal. Apply weld-through primer to the bare-metal areas.

Fit the replacement outer rocker panel over the original part. Line up the replacement panel and scribe a cut line on the original part. This will align the panels. Another way to do this is to cut both panels at the same time. This will leave a gap (the thickness of the blade or cut-off wheel) between the panels. Punch plug weld holes in the original part. Sand all weld areas to bare metal and apply weld-through primer. Then, weld the inserts in place.

Fit up the replacement rocker panel. With the panel held in position with sheet metal screws, test fit the doors, and make the necessary adjustment. When the panel is aligned correctly, weld it in place. Make the plug welds first, and then skip weld the butt joints.

Dress the welds and clean the panel. Scuff sand the rocker panel and spray epoxy primer inside and out. On some vehicles, the outer rocker panel does not need to be sectioned; the entire outer rocker panel can be installed. On these types of vehicles, a STRSW can be used for most of the welds. MIG plug welds will be required where the STRSW cannot reach. Apply the topcoat and rustproofing. Finally, reassemble the vehicle.

Used rocker panels may be installed along with portions of the A-pillar and the center pillar. The easiest replacement is the outer rocker panel only. On some vehicles, the design may allow a used inner/outer assembly to be installed as a unit. This should be done only if the inner rocker panel can be welded to the floor from inside the passenger's compartment of the vehicle and the entire inner/outer rocker panel assembly can be installed rather than spliced to the original rocker panel. If this is not possible, the used assembly must be separated into individual parts and installed in the same manner as new parts.

Center Pillar

The parts of a center pillar are shown in **Figure 17-37**. The center pillar may be part of a door opening surround or a uniside. In some repairs, only the outer panel of the center pillar is replaced. If both the inner and outer panels are needed, an offset butt joint is recommended. When the center pillar is damaged, the roof or the rocker panel may also be damaged.

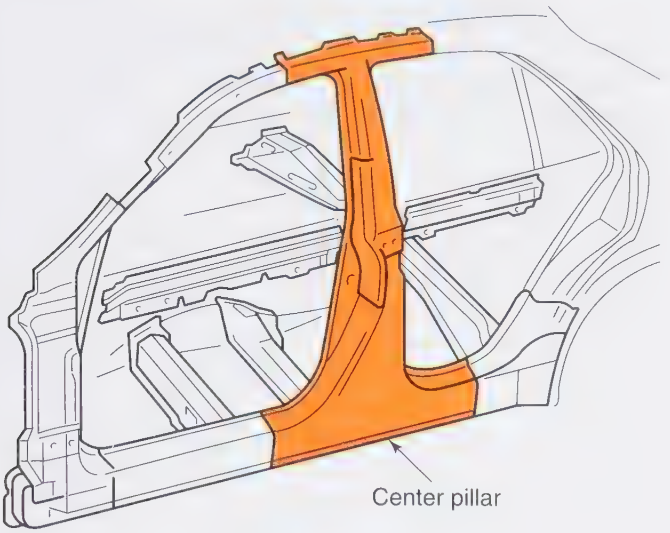


Figure 17-37. *The center pillar consists of inner and outer panels. Internal reinforcements are not shown. (Toyota)*

Begin center pillar replacement by removing the interior trim from the pillar. If both the inner and outer panels will be replaced, remove the front seats from the vehicle as needed. Remove the seat belt mounted on the pillar. Also remove the rear seat and roll the carpet out of the way. The headliner should also be removed if the welding will be within 12" of it. Finally, remove the rear door from the vehicle.

Take measurements to determine the extent of the damage. If necessary, make pulls to align the unibody. Measure again to verify the alignment.

After the unibody has been aligned, you must decide where to make the cuts. Sectioning is usually done at the top of the pillar. Avoid sectioning in the reinforced area around the seat belt bolt. After determining the sectioning location, measure and rough cut the center pillar and drill out the spot welds. Support the roof to prevent sag.

Measure and cut the section joint on both the inner and outer parts of the replacement pillar, if both are needed. A butt joint with an insert may be used if an offset butt joint is not practical. Cut out inserts from the unused portions of the replacement pillars. If both inner and outer center pillars will be used, punch or drill plug weld holes in the flange of the outer center pillar. The number of plug welds you make should match the number of factory spot welds.

Remove the paint from the flange of the inner center pillar and apply weld-through primer. If only the outer panel will be used, punch or drill plug weld holes in the flange of the outer panel. Grind off the weld nuggets. Clean and strip the flange of the existing inner center pillar and apply weld-through primer.

Position the replacement pillar and scribe a cut line on the original panel. **Figure 17-38** shows two methods of marking and cutting the panel. After cutting, weld the inserts to the existing pillar.

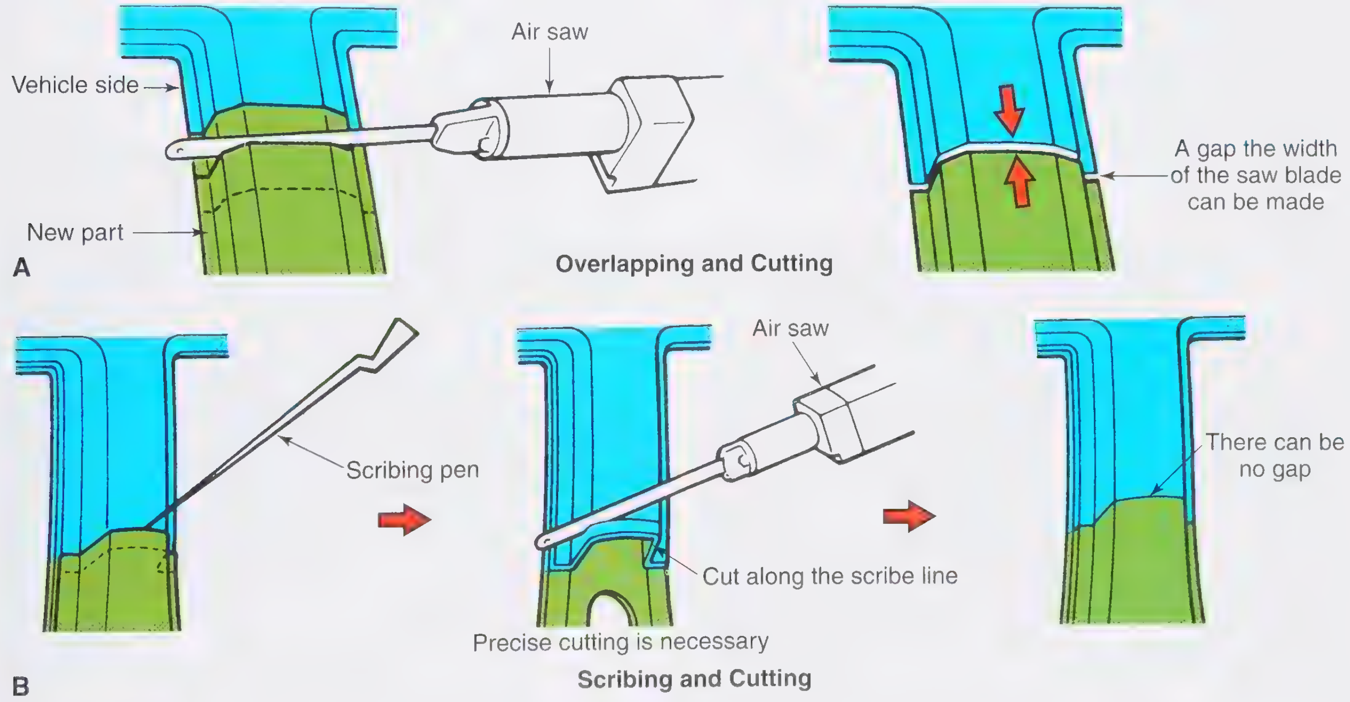


Figure 17-38. *A—Lap the rough cut replacement part over the rough cut existing part and cut the two at the same time. A gap the width of the saw blade will be created between the panels. B—Place the final cut replacement part on the rough cut existing part. Scribe a cut line along the replacement part and make the cut along this line. This practice leaves no gap between the panels. (Toyota)*

Fit up the replacement pillar. After it is positioned correctly and secured, test fit the doors to ensure proper alignment. With the pillar aligned properly, weld it in place. Make the plug welds first. If an offset butt joint is used, stitch weld the butt joint with 3/4" MIG welds. If inserts were installed first, weld the insert to the replacement pillar and then make the continuous weld on the butt joint with a series of skip welds. **Figure 17-39** shows a sectioning of a uniside vehicle. The outer center pillar and outer rocker panel are one part.

After the replacement pillar has been welded into place, dress the welds and clean the pillar and adjacent parts. Scuff sand the parts, spray on epoxy primer, and apply seam sealer. Then apply topcoat and rustproofing. Finally, replace the vehicle interior and reinstall the door.

A used center pillar can be installed as an assembly that includes the outer and inner pillars. The used assembly will be supplied with a cut in the upper center pillar, near the roof. At the bottom, it will include a portion of the rocker panel and floor. If both inner and outer pillars are needed, do not separate the panels. If the vehicle is not a uniside, the center pillar is spot welded to the rocker panel, and sectioning should be done near the roof only. The lower joint should be at the factory location on the rocker panel. If the vehicle is a uniside, the upper sectioning joint should be near the roof, the lower sectioning joint for the outer panel should be on the rocker panel, and the lower joint for the inner rocker panel should at the floor. This will be the factory location on some vehicles. If only the outer pillar is needed, separate the outer and inner panels by drilling out the spot welds.

Rear Frame Rail and Trunk Floor

The rear frame rail is sometimes called a ***hat channel***. This is because the assembly formed by the C-shaped rear rail and trunk floor looks like a hat when turned upside down. These rails are often sectioned when replaced.

To replace the rear frame rail, remove the rear bumper and taillights. Take measurements to locate and identify the extent of the damage. Then, align the unibody by pulling and stress relieving. If the frame rail is kinked, the trunk floor will also be damaged. The trunk floor must be straightened before the rear rail can be replaced. Measure again, after straightening, to verify that the unibody is straight.

Obtain sectioning information and determine where the section joint can be located. Use a butt joint with an insert to repair the rail. Drill out the spot welds and rough cut the damaged rail.

Figure 17-40 shows spot welds on the trunk floor being drilled out to remove a damaged rear frame rail. This method allows the holes in the trunk floor to be used as plug weld holes when welding the replacement rail in place, saving time by eliminating the need for punching or drilling new holes in the replacement rail.

Locate the section joint on the replacement part by measuring from a reference point. Cut the replacement rail along the section joint line. Cut inserts from an unused panel and punch holes in the replacement rail for the plug welds. Sand all weld areas to the bare metal and apply weld-through primer. Measure and final cut the original rail. Dress the plug weld nuggets. Sand all weld areas to bare metal. Apply weld-through primer and weld the inserts in place.

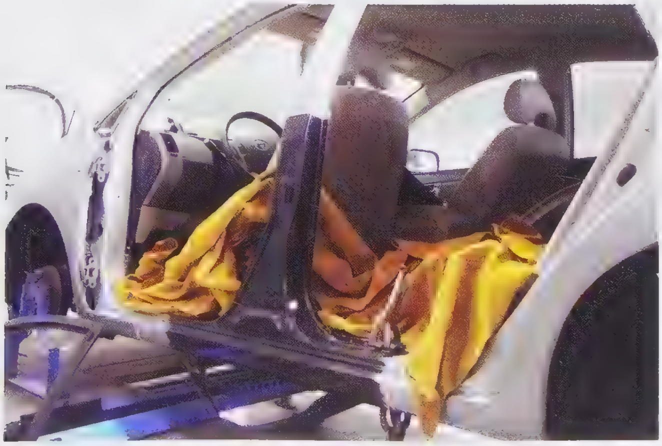


Figure 17-39. *This vehicle has a uniside. The outer center pillar and rocker panel are sectioned.*

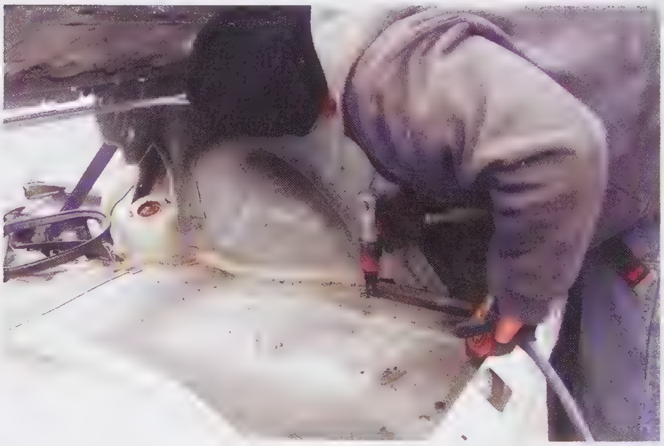


Figure 17-40. *Rear rail is removed by drilling out spot welds in the trunk floor. These spot welds can also be drilled out from under the vehicle.*

Fit up the replacement rail. Use sheet metal screws to hold the rail in place for final measuring and welding. With the replacement rail properly aligned and installed, weld it into place. Make the plug welds first; then skip weld the butt joint.

After welding, dress the welds and clean the rail and adjacent parts. Scuff sand, spray on epoxy primer, and apply seam sealer. Then, apply topcoat and rust-proofing.

Trunk floors are strong by design due to the spare tire well and factory die-stamped folds, dimples, and convolutions known as crush zones. Damaged trunk floors are often difficult to straighten. If the buckles cannot be removed by pulling, the trunk floor should be replaced. In necessary, the trunk floor can be replaced at the factory seams. If this is not practical, the damaged floor should be cut so that a 1" overlap is left. The replacement floor is placed on top of the overlap and welded. See **Figure 17-41**.

Used rear frame rails are usually part of an assembly, such as the rear frame rails, rear body panel, and trunk floor. If, for example, only the rear body panel and the frame rails are needed, remove them from the trunk floor. Keep the rear body panel and the rear frame rails together. Section the rear frame rails using butt joints with welded-on inserts. Replace the entire rear body panel. **Figure 17-42** shows a unibody vehicle that has been cut and is ready for replacement of the rear body panel, trunk floor, and quarter panels with a used assembly.

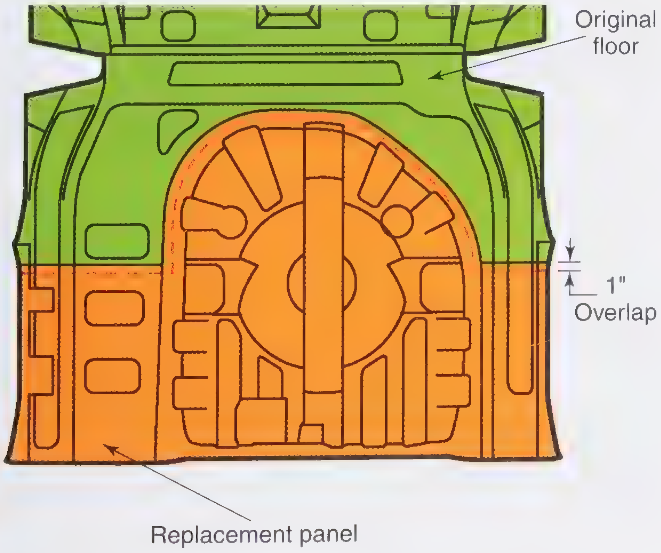


Figure 17-41. *In this trunk floor replacement, the manufacturer recommends that the replacement floor be trimmed to overlap the existing floor. (Toyota)*

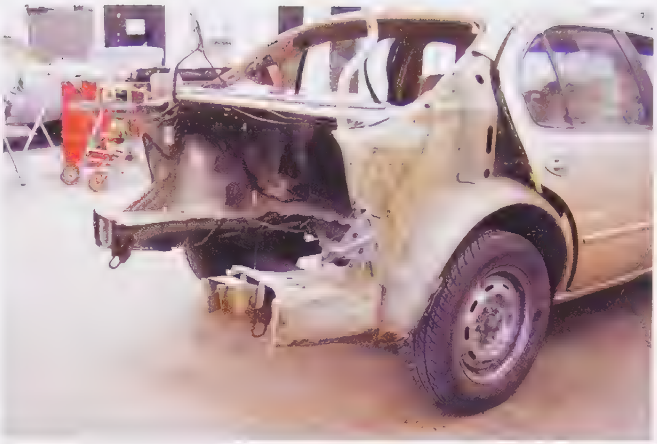


Figure 17-42. *On this vehicle, the trunk floor and quarter panels will be installed as an assembly. The trunk floor will be installed at the factory seam on top of the rear frame rails.*

Clipping

As previously mentioned, clipping involves welding a salvaged rear section and roof to an undamaged front section. Procedures on how to properly clip a vehicle are provided by TECH-COR and I-CAR. Clipping is not recommended by some vehicle manufacturers. In general, clipping involves only three types of joints:

- Windshield pillar sectioning. The windshield pillars are cut near the center to avoid reinforcements. Inserts are made from unused portions by trimming. The inserts are welded either to the rear clip top or the original front pillar, depending on the angle. A steep angle may make it difficult to mate the pillar pieces together.
- Rocker panel sectioning. Like the windshield pillar, a rocker panel is sectioned using a butt joint with an insert. The inserts are cut from an unused rocker panel and welded inside the original rocker panel. Plug welds and stitch welds hold the joint together.
- Floor sectioning. The floor has a 1"–2" overlap with the rear clip floor on top of the original front. This makes the seam under the vehicle face the rear. This seam will be stitch welded on the bottom and plug welded on top.

As with other structural panel replacements, the unibody must be measured and straightened before any cutting is done. The gas line, brake lines and cable, and electrical wires must be moved before the damaged vehicle is cut. Once the two halves are mated together, sheet metal screws are installed at the section joints. Careful measuring should be done next. The doors and glass should be test fit. All dimensions should be confirmed.

Then the joints are MIG welded. The welds should be dressed and the parts cleaned. Spray with epoxy primer and topcoat. The inside of the rocker panels and pillars should be primed and sprayed with rustproofing. The floor seam should be caulked inside and outside before applying the topcoat. **Figure 17-43** shows a clip in progress. The inner rocker panels have been welded and the lap joint on the floor is visible. The outer rocker panel has been cut out enough to allow welding of the inner rocker panel. An insert will be welded on the existing rocker panel, and the replacement rocker panel and a section of outer rocker panel will be welded to it.

Replacing Full-frame Components

Cross members and suspension mounts may be damaged or torn off during a collision. Cross members are bolted, riveted, or welded in place. Damaged cross members can be left in place during frame straightening. The force of corrective pulls on the direct damage will be transferred through the cross members. In this way, the damage is removed opposite of the way it occurred. Once the frame is straightened, a new cross member can be installed.

Some crossmembers are welded in place and must be cut from the vehicle if damaged. If the damaged cross member interferes with pulling the frame, remove the cross member. Cutting out a welded cross member can be a time-consuming procedure. Use a cut-off wheel on the weld. You can also use a plasma cutter to remove the damaged cross member and then grind away the remaining weld. After the frame has been straightened, weld in a new cross member.

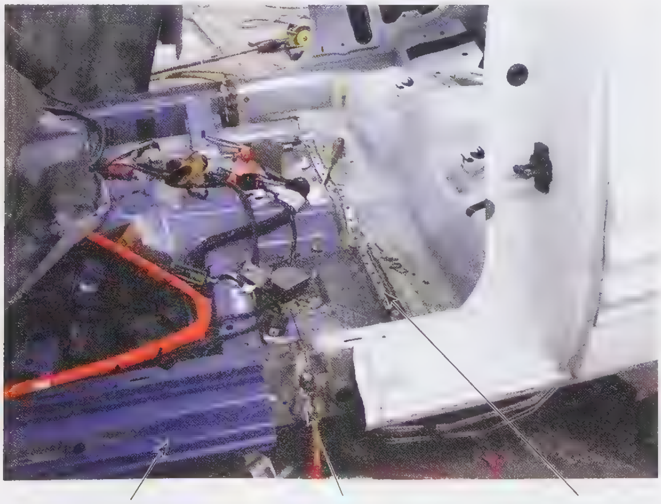


Figure 17-43. *The floor and rocker panel joints are visible in this clipping repair.*

Other cross members and suspension mounts are riveted in place. See **Figure 17-44A**. To remove these components, grind the heads off the rivets with a cut-off wheel. Knock the remaining rivet out with a punch. Use SAE Grade 8 bolts and fasteners that are the same diameter as the hole when installing the replacement cross member or suspension mount. The bolts must fit tightly. Some manufacturers recommend that the holes be drilled out to a diameter one bolt size larger. The Grade 8 bolt should have a shoulder. The shoulder — not the threads of the bolt — should be in contact with the edge of the hole. See **Figure 17-44B**.

Full-frame Sectioning

Some full-frames are designed so that damaged end sections can be replaced with OEM section parts. **Figure 17-45** shows an example. Any frame damage

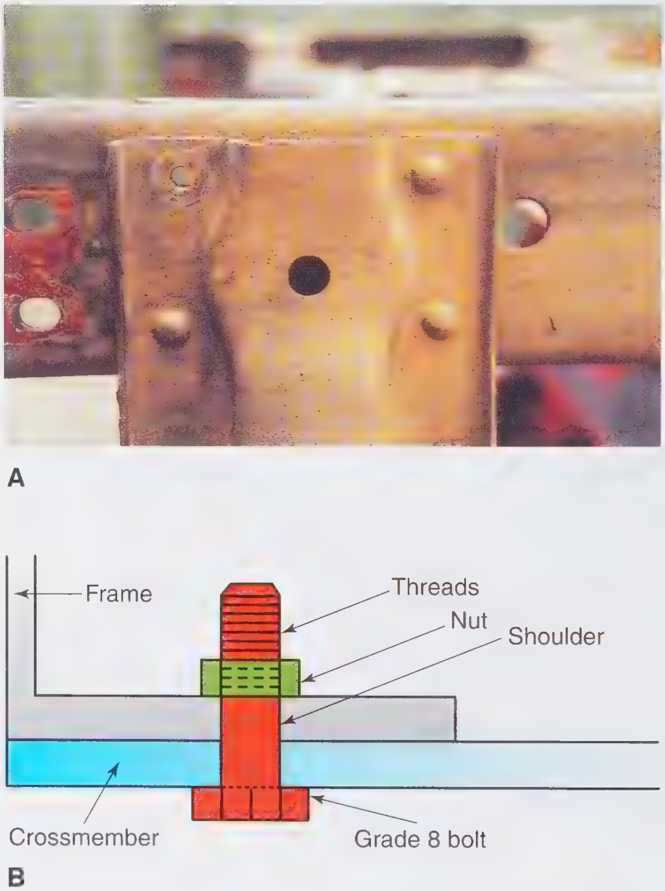


Figure 17-44. *A—Rivets hold crossmembers and suspension mounts in place. B—Replace rivets with Grade 8 bolts and nuts.*

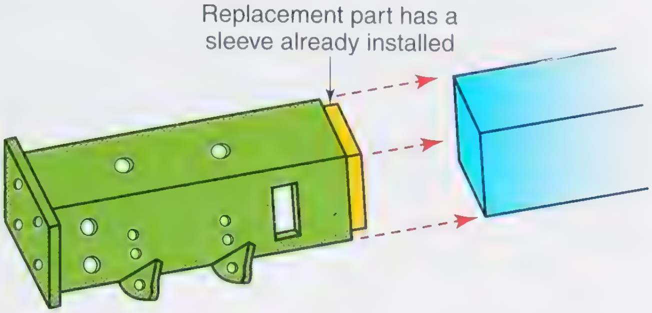

Replacement part has a sleeve already installed

Figure 17-45. *This OEM replacement front section has a sleeve installed. The existing frame is cut at the die mark and the replacement section slides into place.*

outside the sectioning area must be straightened before the frame is cut. Remove any parts that may interfere with the process, such as the radiator, condenser, fenders, hood, front bumper, and radiator support. The existing frame has a die mark to indicate the sectioning location. Find the die mark on the top and bottom of the frame. Mark the cut line by stretching masking tape from die mark to die mark. Cut the damaged frame at the cut line with a reciprocating saw or a cutoff tool. Bevel the edge of the existing frame rail to a 45° angle. The replacement part has the sleeve installed. Remove the paint from the weld area on the replacement part and apply weld-through primer. Slide the replacement part into the existing frame rail and clamp it in place. Make measurements to verify that the replacement rail is properly positioned. Weld the upper and lower horizontal surfaces with a continuous MIG weld. Then weld the inner and outer vertical surfaces with a continuous MIG weld. Grind the welds and apply epoxy primer.

If the fronts of both frame rails are damaged, there is a replacement part that includes rail sections for both rails, as well as the front cross member. This assembly is installed in a similar way to the one-side repair explained previously—straighten the frame, remove parts, locate the die marks, cut the frame, bevel, prep the replacement parts, install, measure, and weld.

The rear of full-frame vehicles can be sectioned at the factory joint. To make this repair, the frame must be straightened before the rear section is cut off. Measuring is used to confirm that all damage has been removed. After removing the damaged rear section, a new section can be installed. The joint is stitch MIG welded, dressed, and sprayed with epoxy primer. The procedure is very similar to that explained previously. These rear end sections—either two rails and cross members or one rail by itself—are available from one manufacturer for select vehicle models.

Full-frames may be sectioned with used parts. A butt weld with a backer joins the used section to the existing frame. In this case, the damaged frame is straightened and the unrepairable portion is cut off. Usually this is an end section. A replacement section is welded in place. A backer that is at least 6" long is welded on the inside of the frame rail. The backer should be made out of the same material as the frame.

Full-frame Replacement

When a full-frame is so badly damaged that it cannot be repaired, the entire frame must be replaced. This is a labor-intensive operation. All wiring; gas and brake lines; suspension, steering, and drive train parts; and sheet metal must be transferred to the new frame. Usually the replacement frame is set next to the damaged vehicle and parts are transferred from the damaged frame to the new frame.

Summary

- Structural components are spot welded, continuously welded, or bolted in place at the factory. During replacement, proper procedures must be followed to ensure that the customer's vehicle will properly protect all occupants in another collision, drive straight, and resist rust.
- All structural components should be aligned before damaged structural parts are removed.
- Sectioning involves removing and replacing the damaged portion of a structural panel. A properly sectioned structural component will be as vibration-resistant and as safe as the undamaged factory-installed panel.
- Structural parts that are commonly sectioned include lower front frame rails, A-pillars, center pillars, rocker panels, and rear frame rails.
- Full replacement means that the entire structural panel is replaced. Examples of components that must be replaced in their entirety include the radiator support, front upper frame rail, outer rocker panel, and in some cases, front lower frame rails.
- The structural panels of a unibody vehicle are held together with welds. The panels are removed by cutting out these welds.
- The purpose of the pretreat step is to prepare the surfaces of both the replacement part and the vehicle for fit up and welding.
- Fit up involves positioning, measuring, aligning, and installing the replacement parts.
- There are several types of joint and weld combinations used to secure structural panels. The type of joint and weld combination used is determined by the manufacturer's recommendations.

- A weld will rust rapidly if it is not properly treated. Proper rustproofing will protect the vehicle from corrosion.
- Foam may be found inside rocker panels and pillars on some vehicles. After the replacement part is welded in and rustproofing has been applied, the foam should be replaced.
- After repairs are made, the vehicle must be reassembled. Reassembly includes the installation or replacement of nonstructural parts.

Review Questions

Please do not write in this textbook. Place your answers on a separate sheet of paper.

1. Explain *sectioning*.
2. What is the greatest concern when sectioning a structural panel?
3. Name three areas that should be avoided when making section joints.
4. A structural panel should always be sectioned in a crush zone. True or False?
5. An entire structural panel is replaced in ______ replacement.
6. When plug welding three layers of metal together, the upper piece of metal should have a(n) ______" hole.
7. When a foam-filled cavity is sectioned, there should be a(n) ______" gap between the foam and the weld.
8. Name three methods used to verify the location of a replacement part prior to welding.
9. Explain how to fit up a replacement panel.
10. A(n) ______ weld is used to join the edges of two panels together.
11. Explain how to make an insert for a butt joint with an insert.
12. Weld ______ can be removed with a sandblaster, wire wheel, or abrasive disk.
13. Seam sealer should be applied before epoxy primer. True or False?
14. Explain why foam may be installed inside vehicle cavities.
15. A salvaged structural part is usually sold as a(n) ______.
16. When installing a used assembly, the assembly should be separated into individual parts and the individual parts should be welded onto the vehicle. True or False?
17. A front ______ consists of all the body parts ahead of the front seat.
18. Explain how to replace a rear section and roof.
19. The position of the shock tower determines steering geometry. True or False?
20. A(n) ______ joint with an insert is used to section inner and outer rocker panels.

ASE-Type Questions

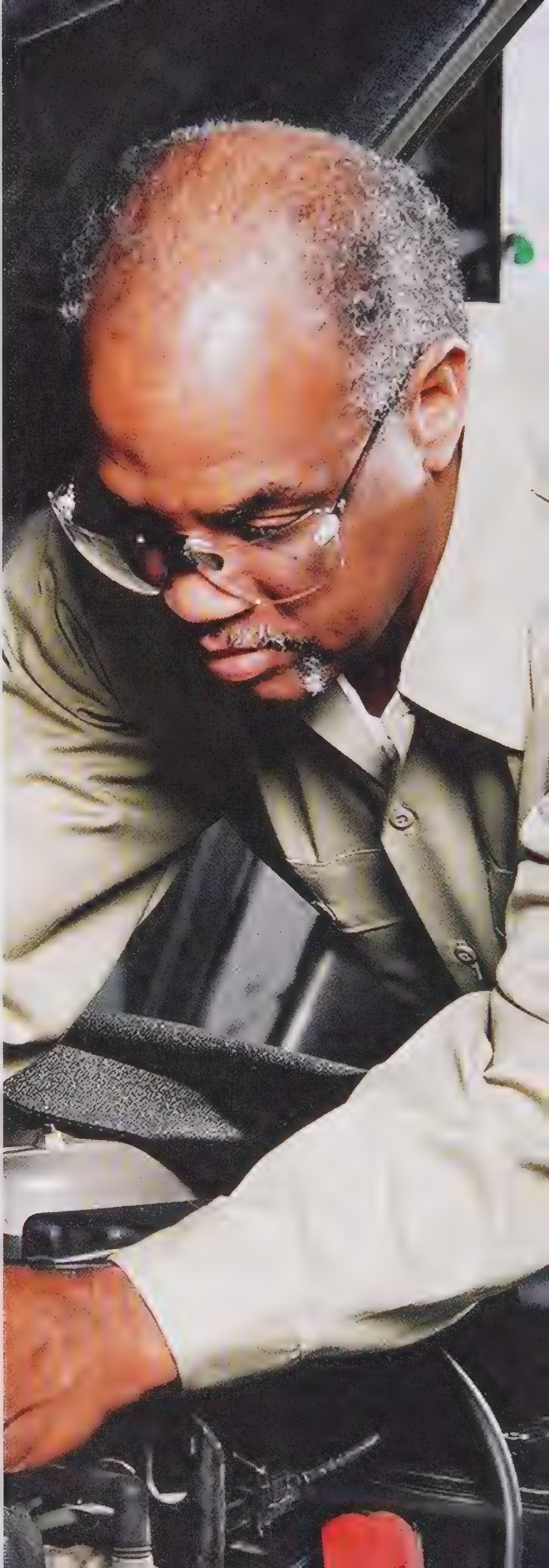
1. The first step in full replacement is to ______.
   (A) straighten the unibody
   (B) drill out the spot welds
   (C) fit up the replacement panel
   (D) disassemble panels to allow access to underlying structural parts
2. Which of the following may be a source of section location information?
   (A) The I-CAR website.
   (B) OEM replacement part instructions.
   (C) Collision repair guides.
   (D) All of the above.
3. When sectioning a structural panel, Technician A wants to avoid suspension mounting locations. Technician B wants to avoid flat areas. Who is right?
   (A) A only.
   (B) B only.
   (C) Both A and B.
   (D) Neither A nor B.
4. A weld nugget must be ground down. Technician A wants to grind the weld and the surrounding metal. Technician B wants to grind the weld only. Who is right?
   (A) A only.
   (B) B only.
   (C) Both A and B.
   (D) Neither A nor B.
5. Technician A says that weld-through primer should be applied to bare metal. Technician B says weld-through primer is not needed if panels have a zinc coating. Who is right?
   (A) A only.
   (B) B only.
   (C) Both A and B.
   (D) Neither A nor B.
6. How much space is required between a weld and cavity foam?
   (A) 1".
   (B) 2".
   (C) 3".
   (D) 4".
7. When plug welding three layers of metal together, what is the size of the upper hole?
   (A) 3/16".
   (B) 1/4".
   (C) 5/16".
   (D) 3/8".

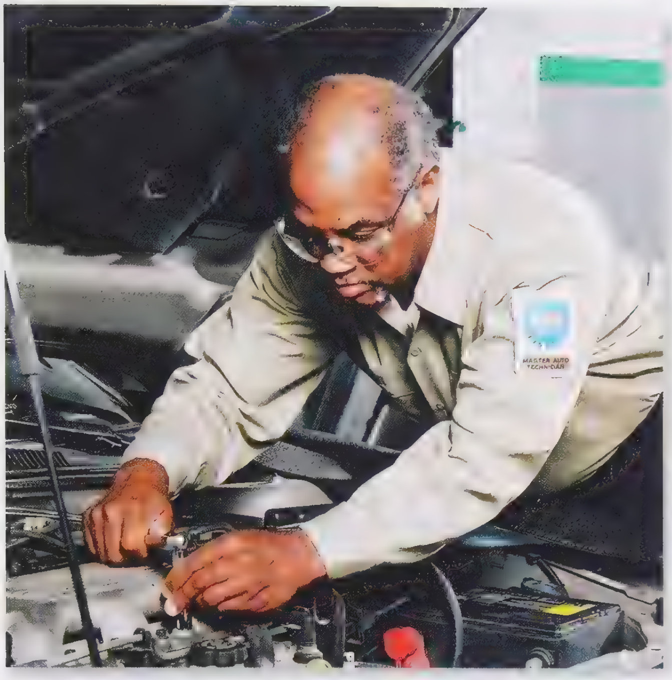
8. All of the following are steps in rustproofing EXCEPT:
   (A) cleaning off weld scale.
   (B) alignment.
   (C) spraying epoxy primer.
   (D) seam sealing.
9. A damaged radiator support is being repaired. Technician A says the radiator support should be sectioned. Technician B says the radiator support should be replaced in its entirety. Who is right?
   (A) A only.
   (B) B only.
   (C) Both A and B.
   (D) Neither A nor B.
10. The manufacturer may allow all the following structural panels to be sectioned EXCEPT:
   (A) the rear frame rail.
   (B) the shock tower.
   (C) the center pillar.
   (D) the lower front frame rail.
11. Technician A says that a full replacement of a lower front frame rail is more time-consuming than sectioning. Technician B says that sectioning should be done at suspension mounting locations. Who is right?
   (A) A only.
   (B) B only.
   (C) Both A and B.
   (D) Neither A nor B.
12. The inner and outer portions of a center pillar must be replaced. Technician A wants to use an offset butt joint. Technician B wants to use a lap joint. Who is right?
   (A) A only.
   (B) B only.
   (C) Both A and B.
   (D) Neither A nor B.
13. All of the following section joints are required when clipping (replacing a rear section and roof) EXCEPT:
   (A) windshield pillar sectioning.
   (B) center pillar sectioning.
   (C) rocker panel sectioning.
   (D) floor sectioning.
14. A riveted cross member must be replaced on a full-frame vehicle. Technician A wants to use Grade 8 bolts and fasteners. Technician B says that the bolt diameter should be the same size as the rivet holes. Who is right?
   (A) A only.
   (B) B only.
   (C) Both A and B.
   (D) Neither A nor B.
15. What is the minimum length of a backer installed for full-frame sectioning?
   (A) 1".
   (B) 2".
   (C) 4".
   (D) 6".

Section 4

Mechanical and Electrical Repairs

Chapter 18. Steering and Suspension
Chapter 19. Electrical System
Chapter 20. Brakes
Chapter 21. Cooling, Heating and Air Conditioning Systems
Chapter 22. Power Train
Chapter 23. Restraint Systems





Chapter 18

Steering and Suspension

Objectives

After studying this chapter, you will be able to:

- Identify the parts of the steering and suspension systems.
- List the function of the parts of the steering and suspension systems.
- Detect damaged steering and suspension system parts by inspection or measurement.
- Explain how to remove and install various steering and suspension parts.
- Define wheel alignment terms.
- List the steps of a wheel alignment.

Technical Terms

ball joints
bushings
camber
caster angle
center link
control arms
cross camber
cross caster
curb weight
electronic suspension system
four-wheel alignment
front-end alignment
idler arm
included angle
MacPherson strut assembly
MacPherson strut front suspension
parallelogram steering gear
pitman arm
pitman sector shaft
race
rack-and-pinion steering system
ride height
setback
shock absorbers
short /long arm suspension
solid rear suspension
springs
stabilizer bar
steering axis inclination
steering column
steering gear
steering knuckle
steering linkage
steering shaft assembly
strut rods
suspension system
thrust-angle alignment
tie rods
tire pressure monitoring system
toe
total toe
tracking
trailing arm
wheel alignment
wheels

Introduction

This chapter covers the operation and repair of steering and suspension systems. Components in these systems are often damaged by collisions that involve impact to a wheel. Damage can be obvious or very subtle. Damaged steering and suspension components should never be straightened. Instead, damaged components must be replaced.

This chapter first looks at the various components of steering and suspension systems, as well as wheel assemblies. Then, common forms of damage found in these components will be discussed. Wheel alignment is also explained.

Steering System

The steering system converts rotation of the steering wheel into left or right movement of the front wheels. There are two basic types of steering systems: rack-and-pinion steering systems and parallelogram steering systems.

NOTE

Some vehicles are equipped with four-wheel steering systems. In these systems, the rear wheels turn slightly with steering wheel movement to allow for a tighter turning radius.

Steering System Parts

Typical steering system parts are shown in **Figure 18-1**. Common steering system components include the:

- Steering column.
- Steering shaft.
- Steering gear.
- Steering linkage.
- Steering knuckle.

The design and operation of these components will be detailed in the following sections.

The ***steering column*** surrounds and supports the steering shaft. The bottom portion of the steering column is perforated metal or a wire mesh. It is designed to collapse during a collision.

The ***steering shaft assembly*** connects the steering wheel to the steering gear. Most steering shaft assemblies consist of upper and lower shafts. The upper shaft is collapsible. Collapsible shafts consist of a solid top section and a hollow bottom section. The sections are held together by a pin. In the event of a collision that throws the driver into the steering wheel, the pin breaks and the solid top section of the column slides into the hollow bottom section. This helps prevent serious injury to the driver.

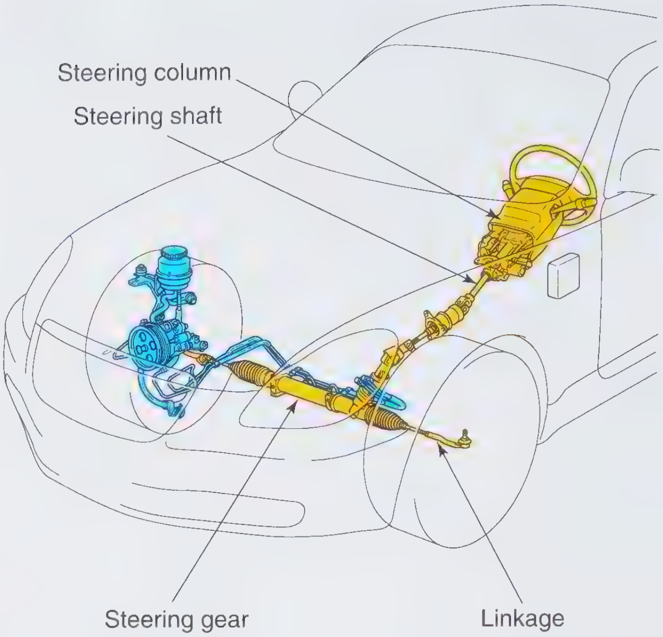


Figure 18-1. *Typical steering system parts. (Toyota)*

The steering shaft assembly may have one or more universal joints. These joints allow the shaft to connect to the steering gear when the path between the steering wheel and the steering gear is not a straight line.

The ***steering gear*** changes the rotating motion of the steering shaft to a back-and-forth movement of the steering linkage. There are two common steering gears in use today: rack-and-pinion steering gear and conventional steering gear. Each type of gear will be discussed in more detail later in this chapter.

The ***steering linkage*** consists of the components that transfer the motion of the steering gear to the vehicle's wheels. The ***steering knuckle*** is the connection between the steering and suspension systems. In automotive suspensions, a steering knuckle is the part that contains the wheel hub or spindle. It is variously called a steering knuckle, spindle, hub, or upright. As the steering linkage moves, it moves the steering knuckle to the left or right. **Figure 18-2** shows an example of a steering knuckle. Each front wheel has a steering knuckle.

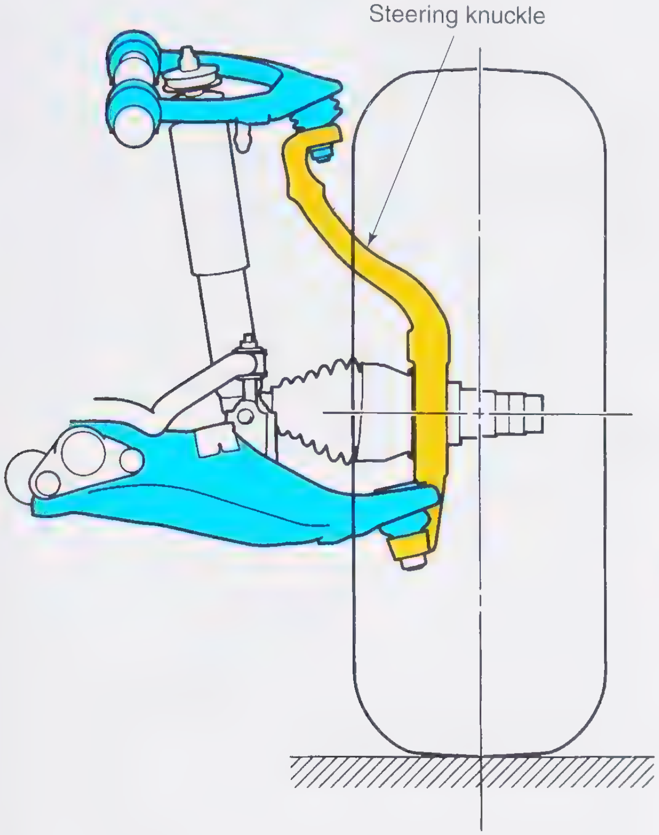

Steering knuckle

Figure 18-2. *This steering knuckle is bolted to the upper and lower control arms. A steering knuckle is also known as a spindle, hub, or upright. (Toyota)*

Steering System Types

There are two types of steering systems used on today's vehicles. The rack-and-pinion system is found on most late-model cars and many light trucks. The parallelogram steering system is found on older cars, as well as some trucks and SUVs.

Rack-and-Pinion Steering

The components of a ***rack-and-pinion steering system*** are shown in **Figure 18-3**. Note the location of the various parts. The rack-and-pinion assembly is bolted to the cowl, engine cradle, or frame. A cross section of a rack-and-pinion assembly is shown in **Figure 18-4**. The major components of this assembly include the rack, which is a toothed rod, and the pinion gear. The pinion gear is connected to the steering shaft. The teeth on the pinion gear mesh with the teeth on the rack. As the steering wheel is turned, the pinion gear rotates.

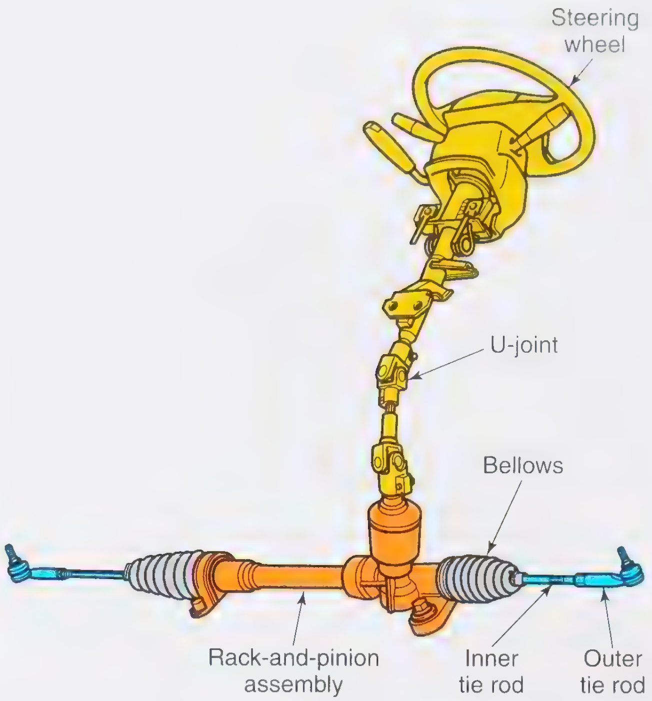

Steering wheel
U-joint
Bellows
Rack-and-pinion assembly
Inner tie rod
Outer tie rod

Figure 18-3. *Rack-and-pinion steering system. Turning the steering wheel causes the outer tie rods to move in unison. (Toyota)*

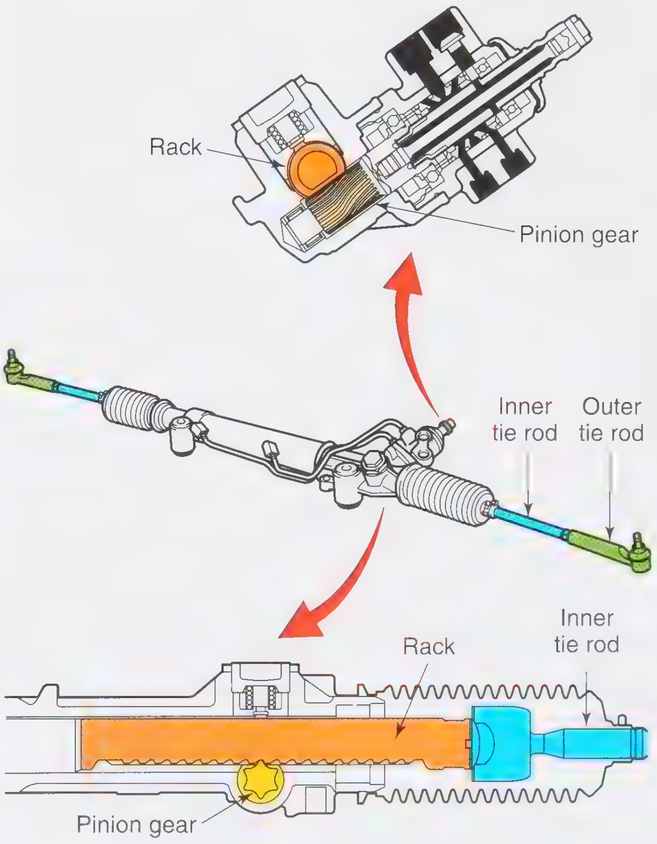

Rack
Pinion gear
Inner tie rod
Outer tie rod
Rack
Inner tie rod
Pinion gear

Figure 18-4. *The rotating pinion gear moves the rack in a rack-and-pinion steering system. (Toyota)*

As the pinion gear rotates, it moves the rack in a straight line. The movement of the rack is then transferred to the linkage to turn the vehicle's wheels in the desired direction.

In a rack-and-pinion steering system, the steering linkage consists of inner and outer tie rods. One inner tie rod is connected to each end of the rack. One end of each outer tie rod is connected to an inner tie rod. The other end of the outer tie rod is connected to the steering arm.

Flexible plastic bellows cover and protect the steering rack and inner tie rod connection. A small plastic or metal tube connects the left and right bellows. This tube equalizes the air pressure between the bellows.

Parallelogram Steering

The parallelogram steering system uses many of the same components as a rack-and-pinion system, such as a steering wheel and a steering column. An example of a parallelogram steering system is shown in **Figure 18-5**.

The ***parallelogram steering gear*** takes the rotating action of the steering wheel, turns it 90°, and transfers it to the ***pitman sector shaft***. The ***pitman arm*** converts the rotation of the sector shaft to a back-and-forth motion and transfers this motion to the rest of the ***steering linkage***.

The steering linkage used in parallelogram systems is more complex than that found in rack-and-pinion systems. The major parts of a parallelogram linkage are the center link, idler arm, and tie rod assemblies. The ***center link*** is moved to the left or right by the pitman arm. The pitman arm supports one end of the center link, while the ***idler arm*** supports the other end. The idler arm is bolted to the vehicle's frame and moves as the center link pivots. Not all parallelogram steering systems have an idler arm.

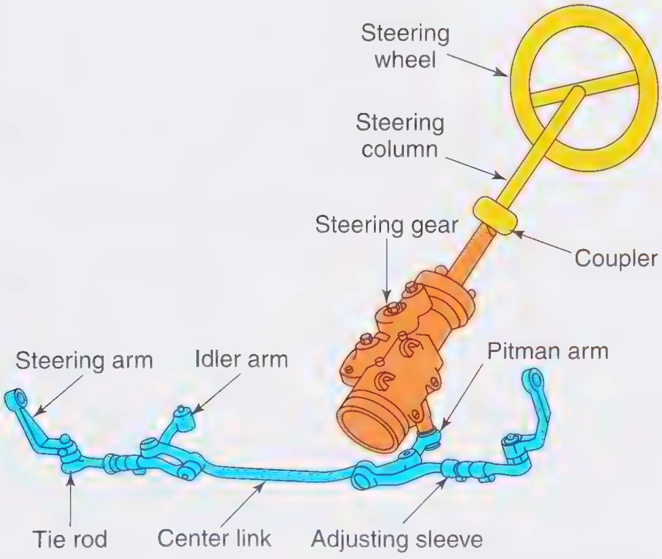


Figure 18-5. *The common parts of a parallelogram steering system are shown here.*

Turning the steering wheel causes the center link to move, which in turn moves the tie rods. The ***tie rods*** provide connections between the ends of the center link and the steering arms. The inner tie rod is connected to the center link. The outer tie rod, or tie rod end, is connected to the steering arm. The movement of the tie rod either pushes or pulls the steering arm, moving the steering knuckles and turning the wheels. An adjusting sleeve is located between the inner and outer tie rods. This sleeve is used to make alignment adjustments. These adjustments will be covered later in this chapter.

Power Steering Systems

A power steering system uses hydraulic pressure to assist the driver's efforts to turn the vehicle's wheels. Power steering is available in both rack-and-pinion and parallelogram systems. The major parts of a power steering system are the power steering reservoir and power steering pump. See **Figure 18-6**.

The power steering reservoir holds power steering fluid. The fluid level is checked in the reservoir. The reservoir may be located on the power steering pump itself or in a remote, but more-accessible, location.

The power steering pump raises the pressure of the fluid in the power steering system. The high-pressure fluid is fed to the steering gearbox or rack-and-pinion assembly through a high-pressure hose. The high-pressure fluid acts on the gears inside the steering gearbox or rack-and-pinion assembly to help the driver

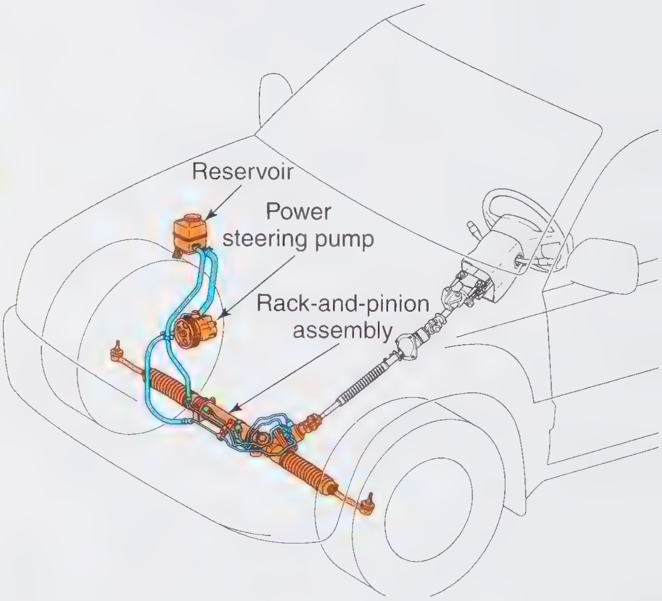


Figure 18-6. *In a power steering system, the power steering pump produces hydraulic pressure to aid in turning the steering wheel. (Toyota)*

turn the front wheels with less effort. A low-pressure hose returns fluid to the pump. The power steering pump may be powered by an engine-driven belt or an electric motor.

Suspension Systems

As a vehicle travels over an uneven surface, its wheels move up and down. The ***suspension system*** isolates the vehicle's body from vibrations caused by the up-and-down movement of the wheels. The suspension system also limits the bouncing of the wheels as they travel over rough surfaces, keeping the tires in contact with the road surface. Control of the vehicle can only be maintained if the tires contact the road.

Suspension System Components

The suspension system is made up of several components that work together to improve a vehicle's ride and handling. These components include:

- Springs.
- Shock absorbers.
- MacPherson strut assemblies.
- Control arms.
- Strut rods.

Springs are the compressible link between a vehicle's suspension and its body or frame. There are three basic types of springs used in automotive suspension systems: coil springs, leaf springs, and torsion bars. See **Figure 18-7**. A coil spring is a helical-shaped steel bar, **Figure 18-7A**. When a vehicle travels over a rough surface, the control arms move up and down. A coil spring compresses when the control arm moves up and extends when the control arm moves down. This type of spring limits the movement of the suspension. Weight added to the vehicle, such as passengers or cargo, causes the coil spring to compress. Coil springs may be found on the front or rear suspension.

Leaf springs, **Figure 18-7B**, are made of several flat pieces of steel held together with straps and bolts. The spring has an upward curve, or arch. Each flat piece of steel is called a leaf.

The leaf spring has an eye at each end. The front eye is mounted to a bracket on the vehicle's frame. The rear eye is mounted to a spring shackle. The spring shackle is mounted to a bracket in the frame. The rear axle housing is bolted to the leaf spring.

NOTE

Some leaf springs are made of a single thick piece of fiber-reinforced plastic.

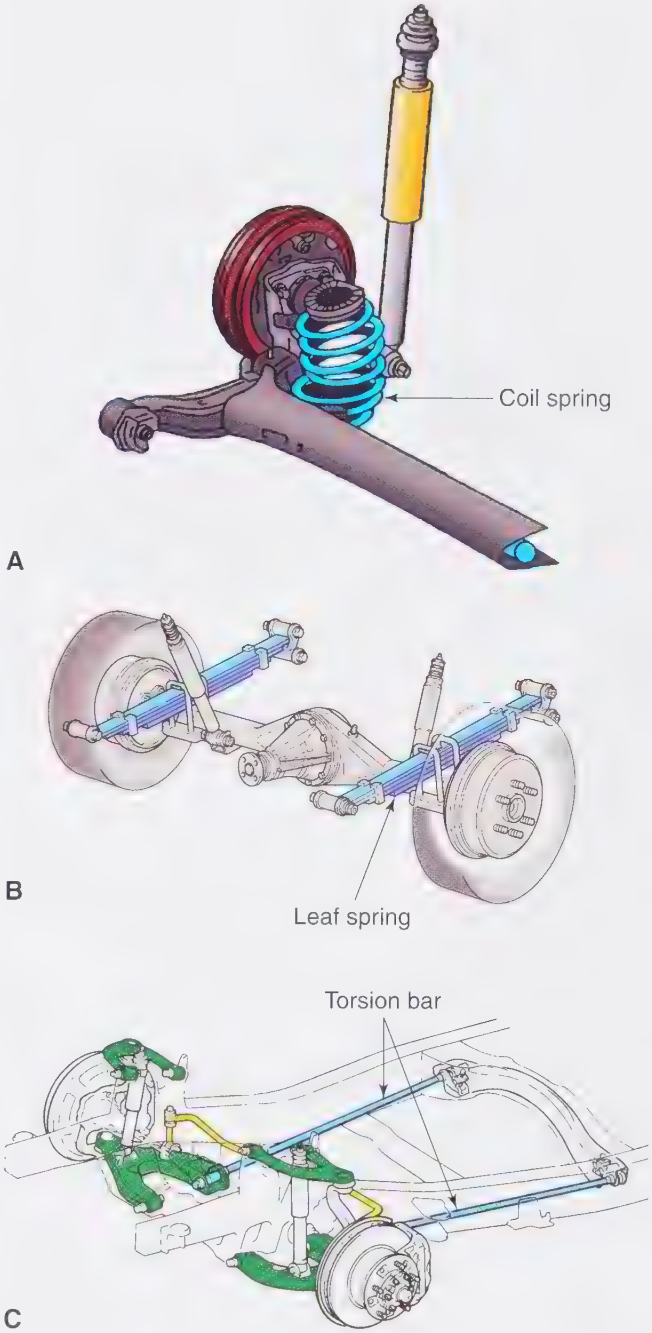


Figure 18-7. *A—Coil springs are found on the front or rear of passenger cars. This coil spring is at the rear wheel. B—Leaf springs on found on the rear of cars, pickup trucks, and SUVs. C—Torsion bars are found on the front of four-wheel-drive pickups and SUVs. (Toyota)*

Pickup trucks, some SUVs, and older rear-wheel-drive vehicles have leaf springs on the rear suspension. Leaf springs are found on the front and rear of some older four-wheel-drive pickup trucks. As weight is added to the bed of the pickup truck, the rear leaf spring gradually loses its arch, or flattens, and elongates. The shackle allows the spring to elongate. In a fully loaded pickup truck, the leaf spring will have no arch. The leaf spring also flexes as the suspension moves up and down as the vehicle travels over rough roads.

Some four-wheel-drive pickup trucks and SUVs have torsion bars instead of coil springs or leaf springs. Torsion bars are longitudinally mounted steel rods. See **Figure 18-7C**. Each end of the torsion bar has a hex-shaped head. One hex-shaped head fits into a hex-shaped hole in the lower control arm, and the other hex-shaped head fits into a hex-shaped hole in a frame cross member. An adjusting bolt at the cross member is used to set the tension on the torsion bar. Adjusting the tension on the torsion bar sets the vehicle's ride height. Torsion bars twist when the vehicle travels over rough surfaces. The up-and-down travel of the lower control arm is limited by the twisting of the torsion bar. Weight added to the vehicle also causes the torsion bar to twist.

The ***shock absorbers***, or shocks as they are commonly called, control spring oscillations (up-and-down movements). Without the shock absorbers, the springs would continue to bounce until all the energy imparted on the spring by the road was dispersed. This would allow the tires to lose contact with the road.

A ***MacPherson strut assembly*** is a self-contained unit that consists of a shock absorber and a coil spring. See **Figure 18-8**. The MacPherson strut provides structural support for the suspension. Therefore, its piston rod is much larger in diameter than the rod in a conventional shock absorber.

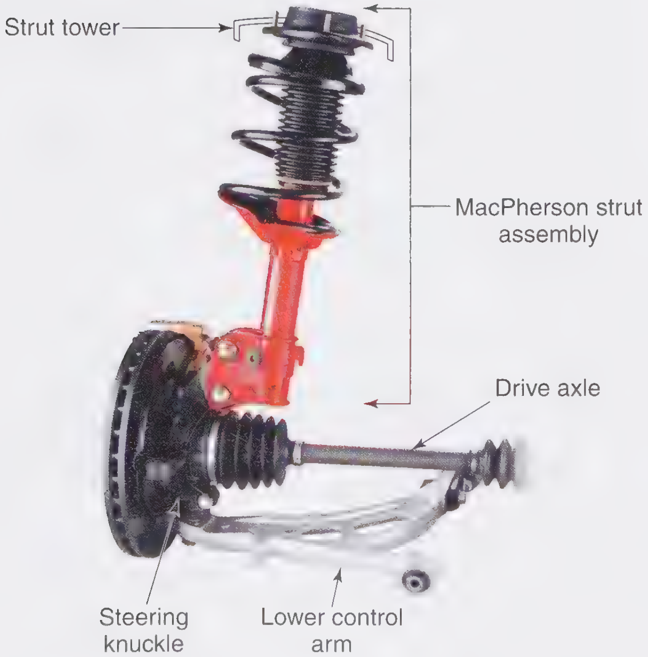


Figure 18-8. *The MacPherson strut assembly is bolted to the steering knuckle and the strut tower.*

Control arms are pivoting suspension components that help maintain alignment of the wheel or axle assembly while permitting needed movement. One end of the control arm mounts to the vehicle's frame or body and the other end is attached to the steering knuckle or axle assembly.

Ball joints are ball-and-socket joints that allow suspension components to move up and down, and from side to side. See **Figure 18-9**. A ball joint is used to connect the control arm to the steering knuckle. The ball joint is pressed, screwed, riveted, or bolted in place on the control arm, **Figure 18-10**. It is connected to the steering knuckle through a tapered stud. The ball joint allows the steering knuckle to turn.

Bushings allow suspension components to move without transmitting vibration and noise to the vehicle's frame or body. The control arm bushings shown in **Figure 18-11** are made of rubber that is bonded to metal. Bolts that run through the bushings hold the control arm in place.

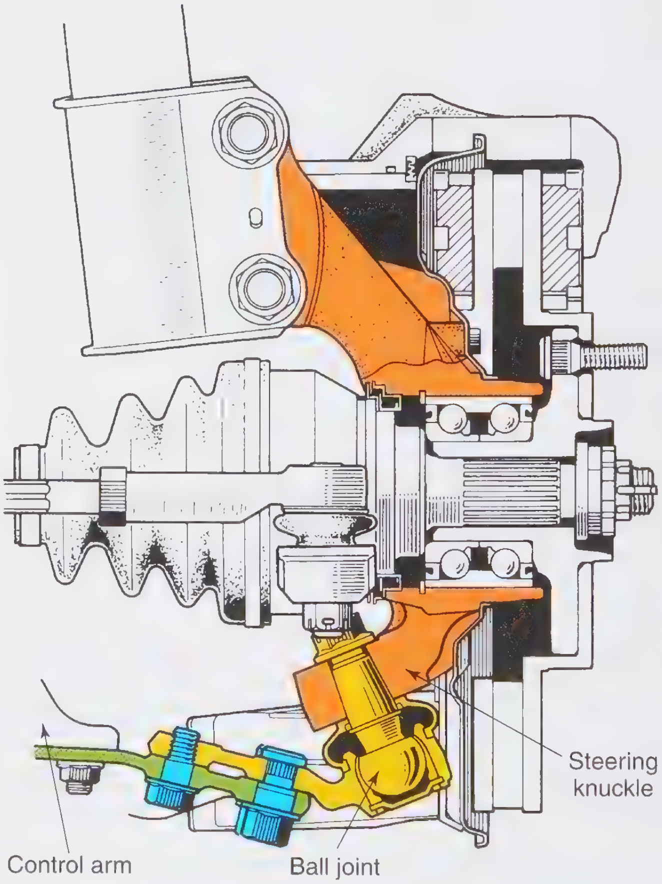


Figure 18-9. *The steering knuckle is attached to the ball joint. The ball joint is connected to the lower control arm. The ball joint allows the steering knuckle to turn. (Toyota)*

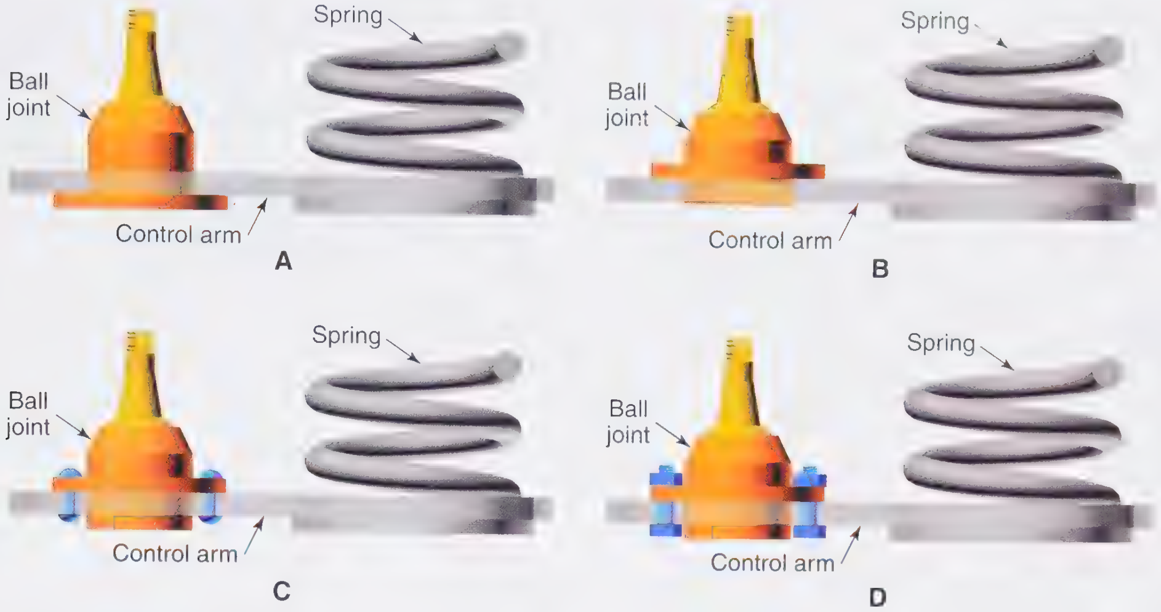

Ball joint
Spring
Control arm
A
Ball joint
Spring
Control arm
B
Ball joint
Spring
Control arm
C
Ball joint
Spring
Control arm
D

Figure 18-10. *Ball joints are installed in one of four ways. A—Pressed-in ball joint. B—Threaded ball joint. C—Riveted ball joint. D—bolted ball joint.*

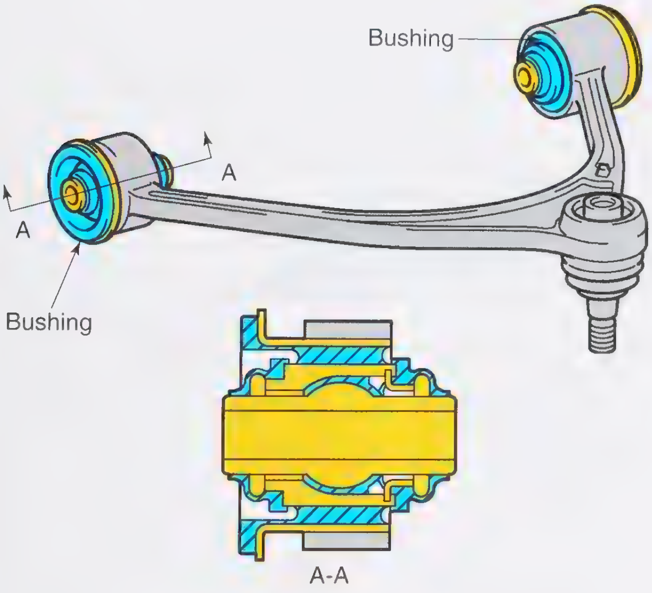

Bushing
A
A
Bushing
A-A

Figure 18-11. *Bushings isolate the body from the movement of the suspension. (Toyota)*

Strut rods are metal bars that are mounted between a vehicle's body and a control arm. They prevent back-and-forth movement of control arms that have a single frame mount. A ***stabilizer bar*** is connected to links bolted to the two lower control arms and minimizes body roll during turns, **Figure 18-12**. For example, when a vehicle turns left, the right side of the car moves down while the left side moves up. By connecting the two control arms, this effect is minimized, keeping the vehicle level.

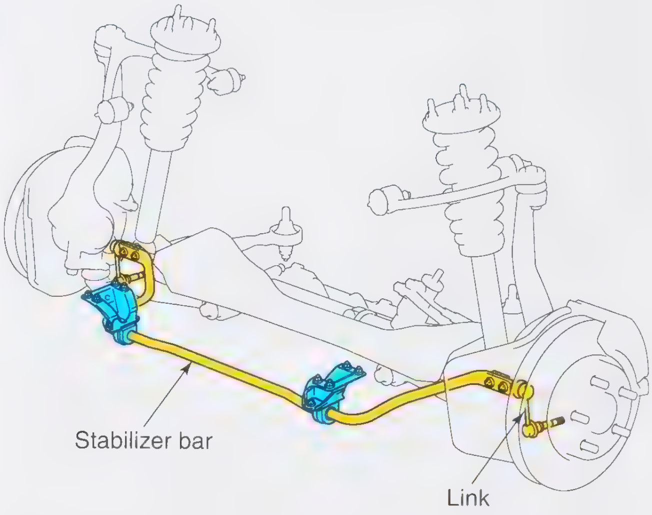

Stabilizer bar
Link

Figure 18-12. *The stabilizer bar connects the lower control arms, minimizing body roll on turns. (Toyota)*

The center of the stabilizer bar is bolted to the frame through bushings. Bushings may also be found at the connection between control arms and the stabilizer bar.

Front Suspension Types

The front suspension components not only absorb road shock but also allow the front wheels to turn. On front-, four-, and all-wheel-drive vehicles, the front wheels also propel the vehicle. The two major types of front suspensions are the MacPherson strut suspension and the short/long arm suspension.

The ***MacPherson strut front suspension*** is found in many front-wheel-drive unibody vehicles. See **Figure 18-13**. In this system, the strut assembly is bolted to the steering knuckle and the strut tower. The strut tower is part of the unibody. The strut assembly rotates as the front wheels are turned. The coil spring allows the wheel to move upward within a certain range without moving the vehicle's body upward. The strut itself acts as a shock absorber. The upper mount holds the spring in place. In most cases, the MacPherson strut assembly must be removed from the vehicle to service its individual components.

The lower control arm connects the lower end of the steering knuckle to the vehicle's frame or engine cradle. One end of the control arm is connected to the steering knuckle through a ball joint. The other end of the control arm is mounted to the frame, unibody, or engine cradle through control arm bushings. Some MacPherson strut systems have both upper and lower control arms. These systems are known as multi-link suspension systems.

A ***short/long arm suspension*** (SLA) system has both a lower control arm and an upper control arm. See **Figure 18-14**. The upper control arm is mounted to the frame or cradle. The upper control arm is also connected to the steering knuckle at the upper ball joint.

The lower control arm is also mounted to the frame, cradle, or unibody. The lower control arm is connected to the steering knuckle at the lower ball joint. The lower

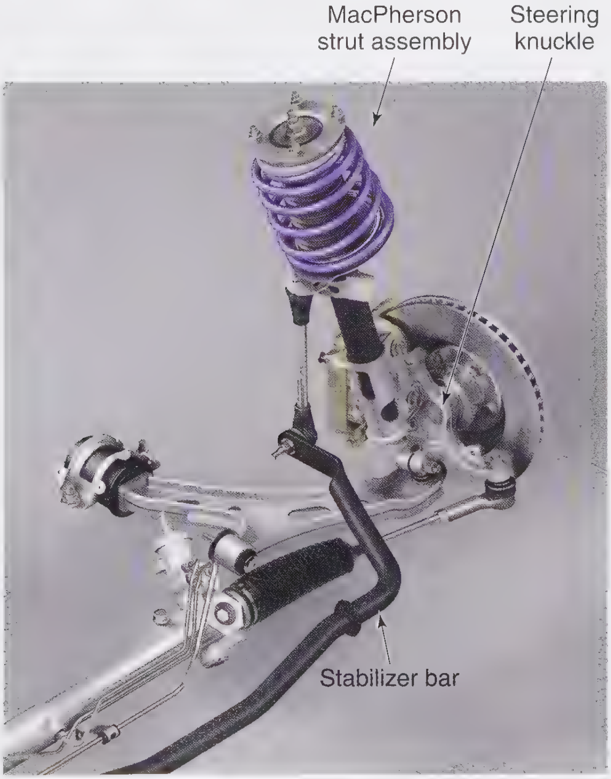


Figure 18-13. *A MacPherson strut assembly is bolted to the steering knuckle and the shock tower. This MacPherson strut has a stabilizer bar. (Ford)*

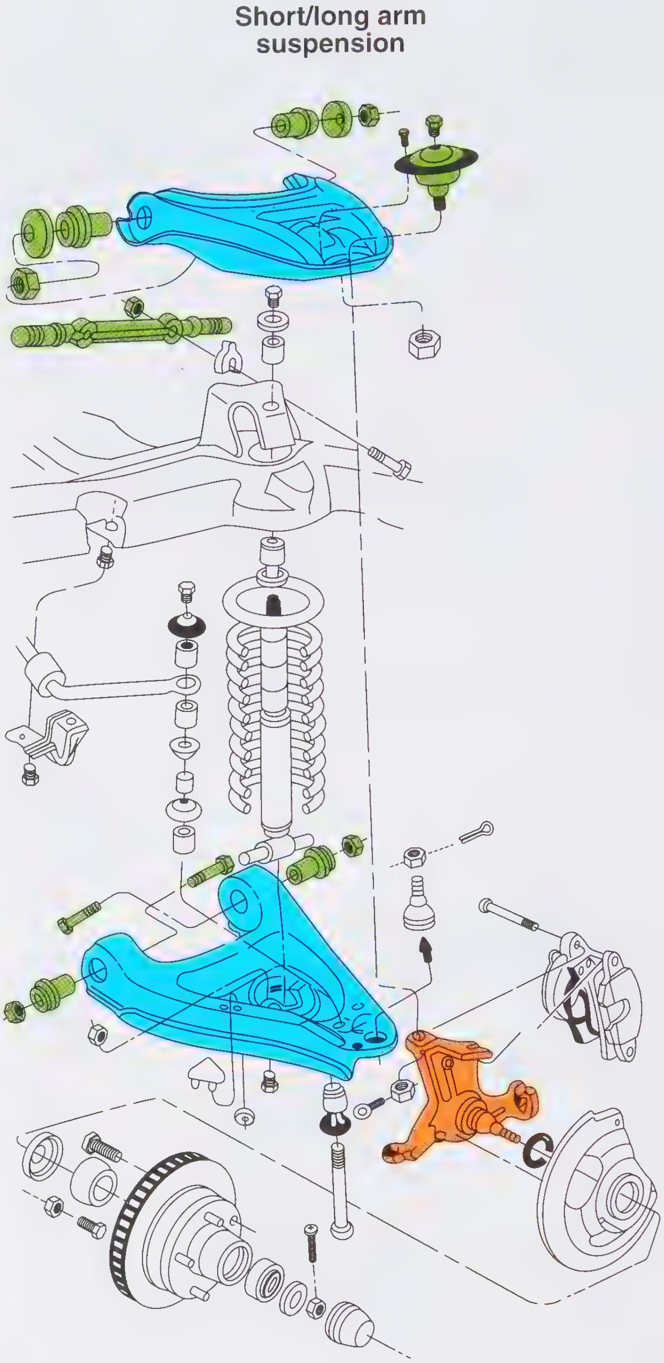


Figure 18-14. *The upper and lower control arms are connected by the steering knuckle. This drawing depicts the front suspension of a rear-wheel-drive vehicle. This robust suspension is typically found on trucks.*

control arm may have a torsion bar or stabilizer bar attached to it. In an SLA system, the coil spring may be mounted between the upper and lower control arms, or between the upper control arm and the body of the vehicle.

There are other types of front suspension systems. **Figure 18-15** shows a twin I-beam suspension system found on Ford trucks. This system has coil springs, shock absorbers, a stabilizer bar, and steering knuckles. Instead of a lower control arm, this system has an I-beam and a radius arm. The I-beam is attached to the frame and the steering knuckle. The radius arm is also attached to the steering knuckle and the frame.

Rear Suspension Types

All rear suspensions contain a spring, a shock absorber or strut, and a specific way to mount the rear wheels. The types of rear suspensions are solid, semi-independent, and independent. This section will look at each type.

A ***solid rear suspension*** has a solid rear axle that connects both rear wheels. If one wheel moves up or down, the other rear wheel is affected. This type of suspension may be found on front-, rear-, four-, and all-wheel-drive vehicles.

A solid rear suspension used on a front-wheel-drive vehicle is shown in **Figure 18-16**. This system has coil springs and shock absorbers. The control arms in this example are attached to the unibody and the rear axle assembly. In this arrangement, the control arm is called a ***trailing arm***. The rear wheels may be mounted on spindles or hubs that are connected to the rear axle assembly.

An example of a rear-wheel-drive solid axle is shown in **Figure 18-17**. Rear-wheel-drive vehicles may have coil springs or leaf springs. This axle assembly drives the rear wheels.

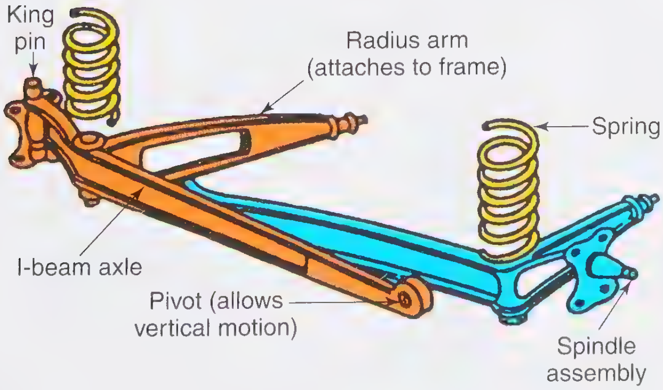

King pin
Radius arm (attaches to frame)
Spring
I-beam axle
Pivot (allows vertical motion)
Spindle assembly

Figure 18-15. *Twin I-beam suspension. The I-beams are supported by radius arms. (Chief)*

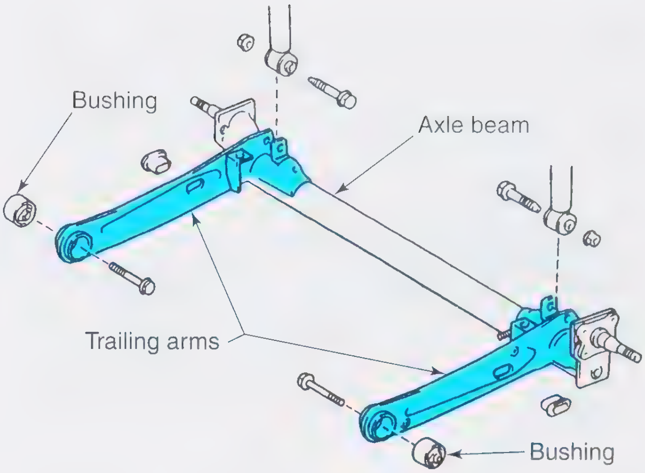


Figure 18-16. *This solid rear suspension from a front-wheel-drive vehicle is attached to the vehicle with bushings. (Toyota)*

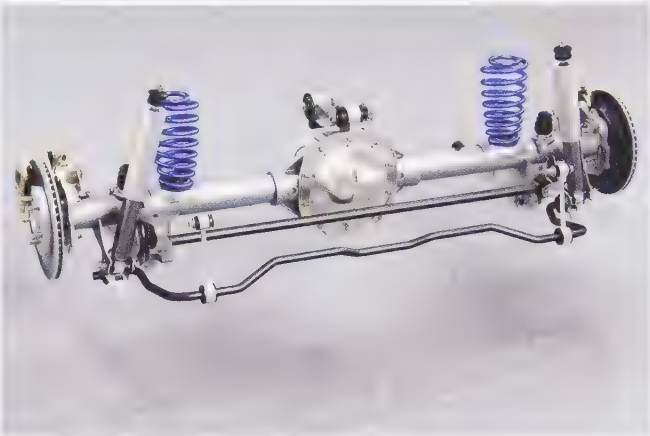


Figure 18-17. *This solid rear axle suspension has coil springs. Note the stabilizer bar. (Ford)*

In a semi-independent rear suspension, each rear wheel can move up and down separately, but there is an axle between the rear wheels. This axle is capable of flexing, thereby reducing the transfer of motion from one rear wheel to the other. A semi-independent rear suspension is shown in **Figure 18-18**.

In an independent rear suspension, each rear wheel can move up and down without affecting the other. **Figure 18-19** shows an independent rear suspension on a four-wheel-drive vehicle. Independent rear suspensions are also found on rear-wheel-drive vehicles.

Electronic Suspension Systems

As a vehicle is driven, the ride height constantly changes. Braking causes the front of the vehicle to dive.

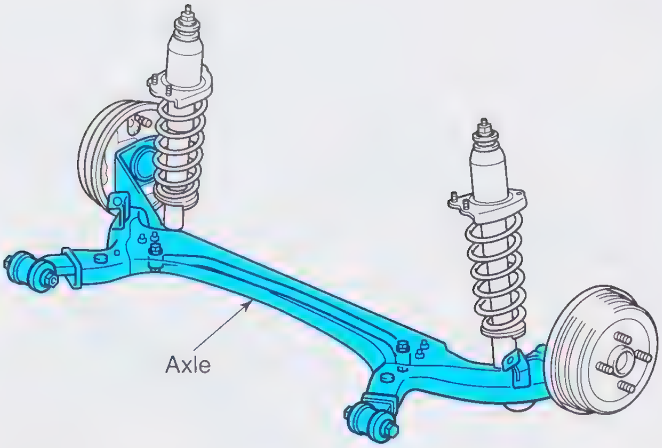


Figure 18-18. *The semi-independent rear suspension can flex as the vehicle travels over bumps in the road. This reduces the transfer of motion from one rear wheel to the other. (Toyota)*

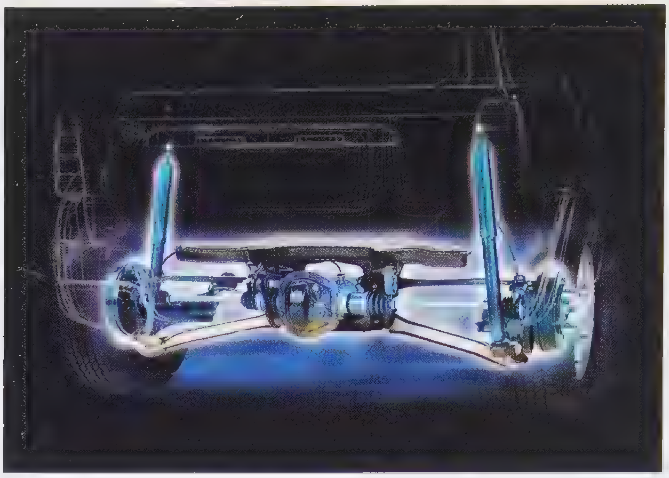


Figure 18-19. *In an independent rear suspension, each rear wheel can move up and down without affecting the other. (Ford)*

Acceleration of a vehicle causes the rear end to drop. Turning causes the vehicle body to roll. The ***electronic suspension system*** keeps the vehicle level during these maneuvers, as well as when carrying different weight loads of cargo and passengers. One type of electronic suspension system is shown in **Figure 18-20**. The air springs take the place of the coil springs and shock absorbers. In this system, air is added to or removed from air springs to keep the vehicle level. An onboard air compressor provides the air to fill the springs. Height sensors, which are located at each spring, relay information on the height of each corner of the vehicle to the control module. The control module then decides on an action and sends a signal to the air compressor or another device.

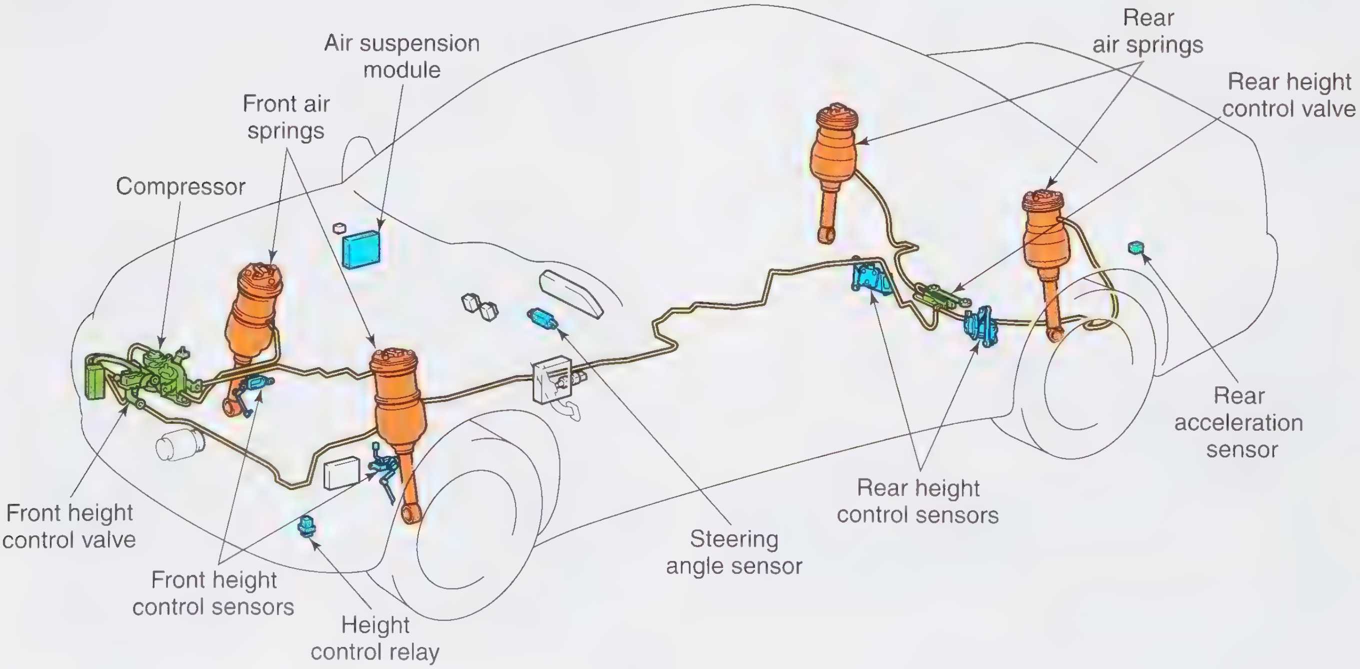

Air suspension module
Front air springs
Compressor
Rear air springs
Rear height control valve
Front height control valve
Front height control sensors
Height control relay
Steering angle sensor
Rear height control sensors
Rear acceleration sensor

Figure 18-20. *In an electronic suspension system, height control sensors send information to a control module. The control module causes air springs to inflate or deflate to keep the vehicle level. (Toyota)*

Hub and Wheel Assemblies

The hub and wheel assembly consists of the wheel bearings, wheel, and tire. This section explains these components.

Wheel Hubs and Bearings

The hub provides a mounting place for wheels and tires. In some vehicles, the hub rides on a spindle that is part of the steering knuckle. Wheel bearings allow the hub and wheel assembly to rotate easily on the spindle. **Figure 18-21** shows an example of tapered wheel bearings. In this design, there are two bearings at each wheel. A ***race*** is the surface in the hub that the bearing contacts.

Sealed wheel bearings are used on front-wheel-drive vehicles. There are three types of sealed wheel bearings. The first type, which is called an integral bearing, is part of the hub. The hub is bolted to the steering knuckle or other support. If the bearing wears out or is damaged in a collision, the entire hub assembly must be replaced. **Figure 18-22** shows an integral sealed wheel bearing.

The second type of sealed wheel bearing is pressed in place into the steering knuckle. If the bearing wears out, the worn bearing is pressed out of the knuckle and a new bearing is pressed in place.

The third type of sealed wheel bearing is pressed into a hub. The hub is bolted to the steering knuckle or support. A worn bearing of this type is pressed out of the hub and a new bearing is pressed into place.

Wheels

Wheels are the assemblies on which the tires are mounted. They can be made of steel, aluminum, aluminum/magnesium, or graphite and plastic. A cross section of a wheel is shown in **Figure 18-23**.

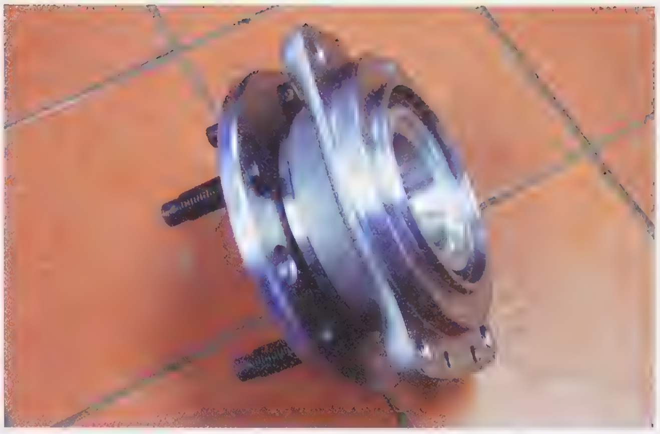


Figure 18-22. *Integral wheel bearing and hub assembly. The entire assembly is replaced if the wheel bearing is bad.*

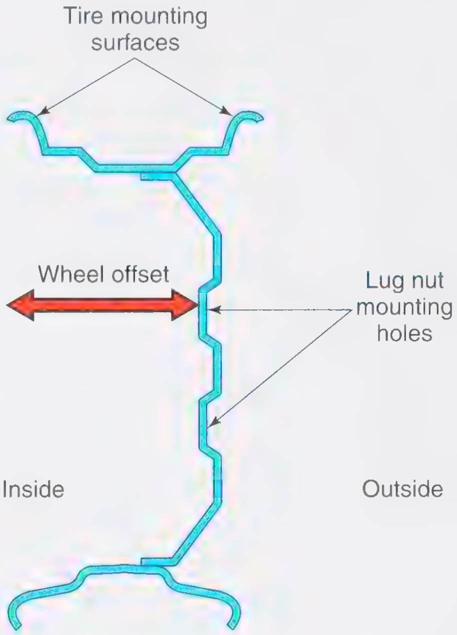


Figure 18-23. *The tire fits into the tire mounting surfaces on the wheel.*

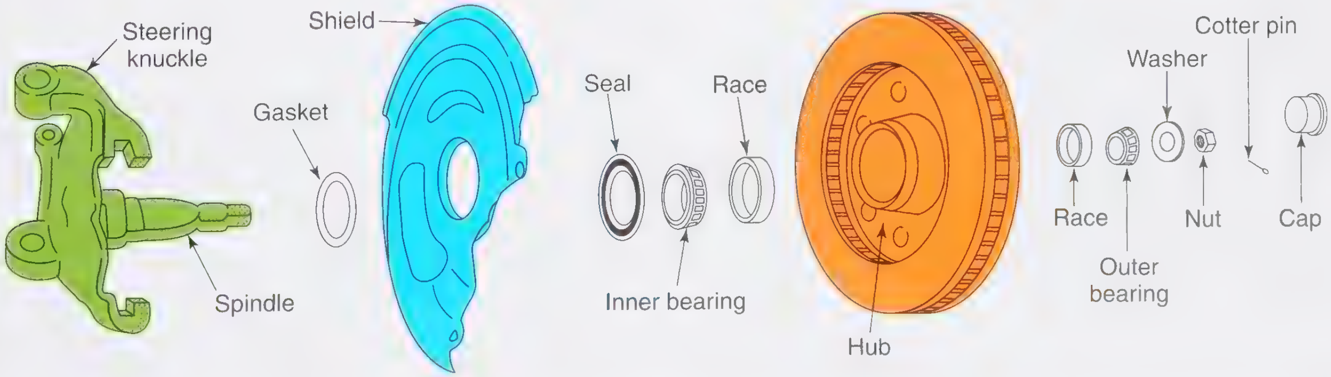


Figure 18-21. *These tapered roller bearings from a rear-wheel-drive vehicle are mounted on the steering knuckle (spindle).*

The diameter of a factory wheel can range from 12" to more than 20". The width of the rim can also vary. Lug nuts or bolts are used to hold the wheel to the hub. Wheels may have four, five, or six bolt holes that fit over wheel studs or accept bolts. Some truck wheels have as many as eight bolt holes. The bolt hole pattern varies from one vehicle manufacturer to another.

Tires

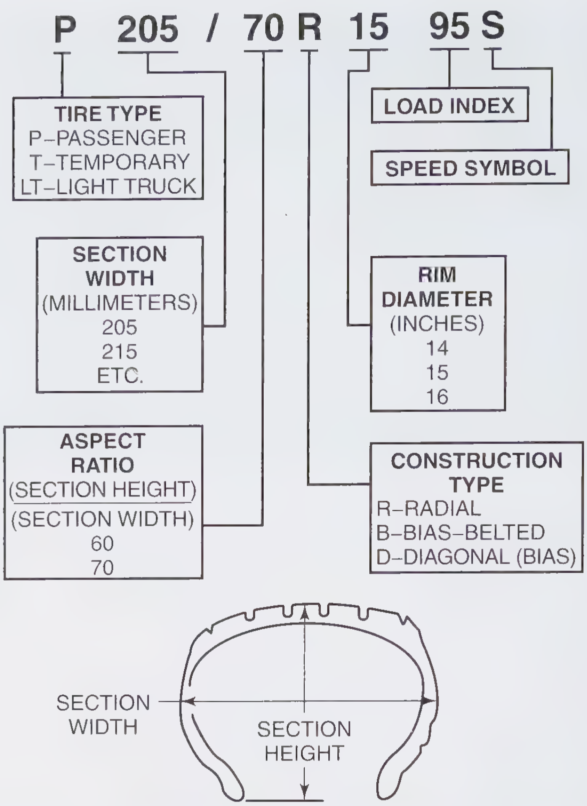
Tires are an important part of the suspension system, as they support the weight of the vehicle and provide a cushioning action. The proper tires play a very important role in a vehicle's ride quality and handling.

There are many types of tires available for use on modern vehicles. The type used depends on the model of vehicle and the conditions under which the vehicle will be used. For example, passenger car tires are different from those designed for use on light trucks. In the past, bias tires were used on virtually all vehicles. Now, radial tires are used exclusively.

The sidewall of a tire is marked with specifications. See **Figure 18-24**. These specifications include the size, load rating, and speed rating of the tire. When replacing a tire, use the tire size and type specified by the vehicle manufacturer. Tire size is given as a P-metric designation or a metric designation. The P-metric is the most common size designation for tires sold in North America. An example of a popular P-metric tire size designation is P205 75 R15. Note that each letter and number has a specific meaning:

- P—Indicates that this is a passenger car tire. Other letters used include LT, which indicates a light truck tire, and T, which indicates a temporary tire.
- 205—Width of the tire cross section in millimeters.
- 75—Denotes the tire's aspect ratio. The aspect ratio of a tire is the ratio of tire section height to its section width. In other words, it is the tire's height divided by its width. In this example, the aspect ratio of 75 means the tire has a section height that is 75% of its section width. Low profile tires have a relatively low aspect ratio, such as 50 or 60.
- R—Denotes radial construction. Other types of construction, such as bias belted (B) and bias, or diagonal (D), are no longer used on modern vehicles.
- 15—Denotes the rim diameter in inches.

Metric tire size designations are generally found on tires produced by European manufacturers. Metric tire designations are similar to P-metric designations. However, the letter representing the type of tire (P, LT, or T) is omitted.



Speed Symbol	Maximum Speed (km/h)	Maximum Speed (mph)
S	160	112
T	190	118
U	200	124
H	210	130
V	240	149
Z	Over 240	Over 149

Figure 18-24. *Tire markings provide important information about a tire, including size, load index, and speed rating.*

The load index is a number that represents a tire's load carrying capacity. The higher the load index number, the greater the tire's load capacity. For example, a tire with a load index of 78 has a load capacity of 937 lb (425 kg), while a tire with a load index of 85 has a load capacity of 1135 lb (515 kg). A tire's load index and proper inflation pressure are both important factures in determining how much load the tire can safely carry.

NOTE

The load rating of a metric tire may be different than that for the same size P-metric tire.

The speed designation consists of a letter that corresponds to the specific maximum speed the tire can sustain. The speed designation is located either after the load index number or between the aspect ratio and tire construction designation. When replacing tires, always choose a tire with a speed rating equal to or greater than the rating of the original equipment tires. Also, make sure all tires on the vehicle have the same speed rating.

Tire Pressure Monitoring Systems

A ***tire pressure monitoring system*** will inform the driver of incorrect tire pressure. Proper tire pressure will help optimize gas mileage and tire life. There are two types of monitoring systems: comparative-pressure systems and actual-pressure systems. A comparative-pressure system uses the antilock brake system (ABS) to determine if the air pressure in one tire is low compared to the other tires. The ABS monitors wheel speed. A tire with low air pressure turns faster than a properly inflated tire. The ABS system will detect if one wheel is turning slightly faster than the other wheels and inform the driver by illuminating a warning lamp. If all the tires are underinflated the same amount, this system could not detect a problem.

The actual-pressure system determines the actual air pressure in each tire. There are two types of actual-pressure systems. One system has a tire pressure sensor strapped to each wheel, inside the tire. The sensors transmit signals to a body control module. The control module illuminates a warning lamp if low tire pressure is detected. The second type of actual-pressure system uses valve stem–mounted sensors. See **Figure 18-25**. One or more receivers are used to pick up the signals from the sensors. The receiver then sends the sensor information to a body control module. If low tire pressure is detected, the module illuminates a warning lamp. Rotating the tires on a vehicle with an actual-pressure tire pressure monitoring system will require programming the new location of each tire into the system.

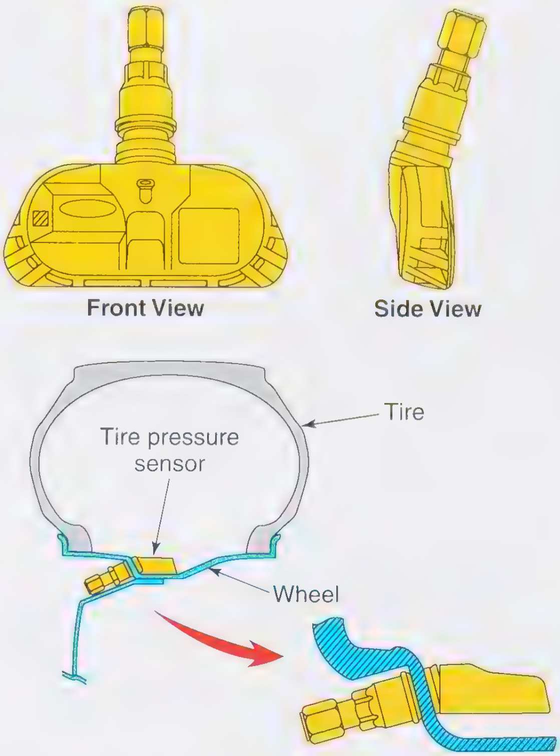


Figure 18-25. *This is a valve-stem type tire pressure sensor. (Toyota)*

Diagnosing Steering, Suspension, and Wheel Assembly Damage

Collisions can damage the steering system, suspension system, or wheel assemblies of a vehicle. Steering system components are commonly damaged by an impact on a front wheel. On a rack-and-pinion steering system, an impact on a front wheel may bend or break the corresponding tie rod and steering knuckle. The rack-and-pinion assembly can also be damaged as the front wheel is pushed back. A damaged rack-and-pinion may leak, or it may bind as the steering wheel is turned. **Figure 18-26** shows a damaged rack-and-pinion steering system.

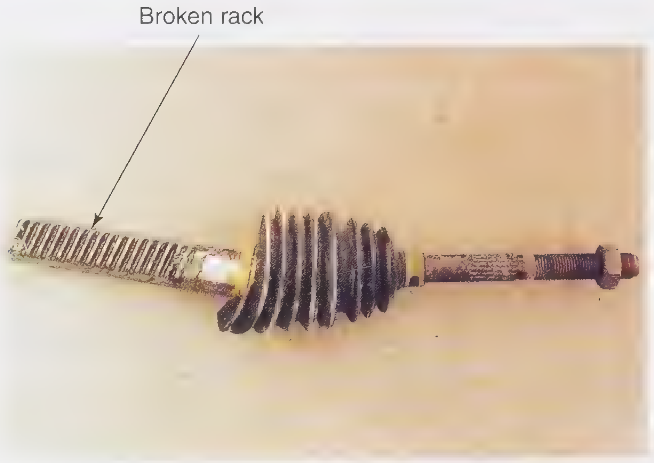


Figure 18-26. *The steering rack was broken and it fell out of the rack-and-pinion steering assembly.*

On a parallelogram steering system, an impact on a front wheel may bend or break a tie rod, tie rod end, or steering knuckle. **Figure 18-27** shows damage to parallelogram steering linkage. A parallelogram steering gearbox may also be damaged by an impact on a front wheel. For example, splines on the pitman sector shaft may be twisted. See **Figure 18-28**. **Figure 18-29** shows a pitman sector shaft that has been broken by an impact on a wheel. Internal gearbox damage may also be present.

Frame damage can also cause damage to a parallelogram steering system. As a full-frame moves during a collision, the movement may cause the center link or tie rods to bend. Even if the center link or tie rods are not bent, the damaged frame may interfere with the movement of the center link, causing a binding or scraping as the steering wheel is turned.

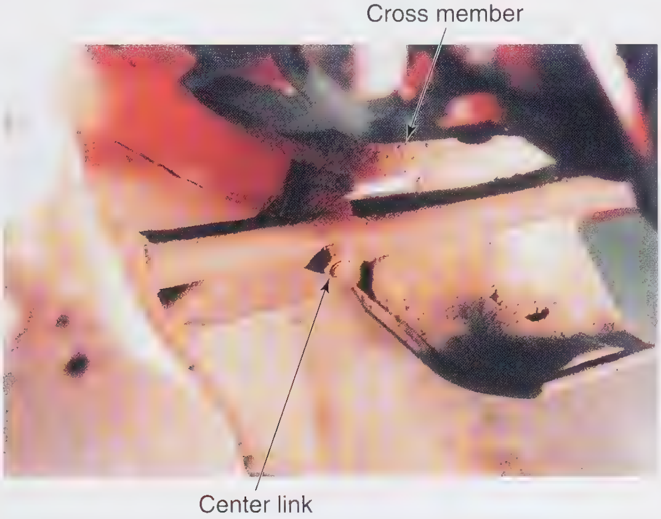


Figure 18-27. *This center link was pushed into the engine cross member. Binding prevents the steering linkage from moving.*

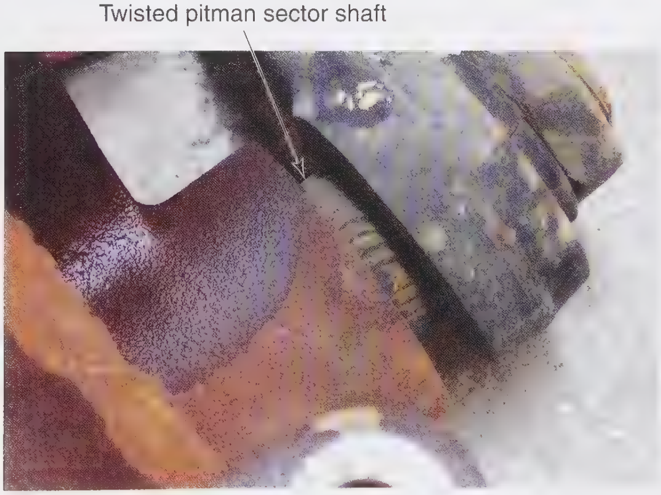


Figure 18-28. *An impact on the right front wheel as the driver turned the steering wheel to the left caused the twist in this pitman sector shaft.*

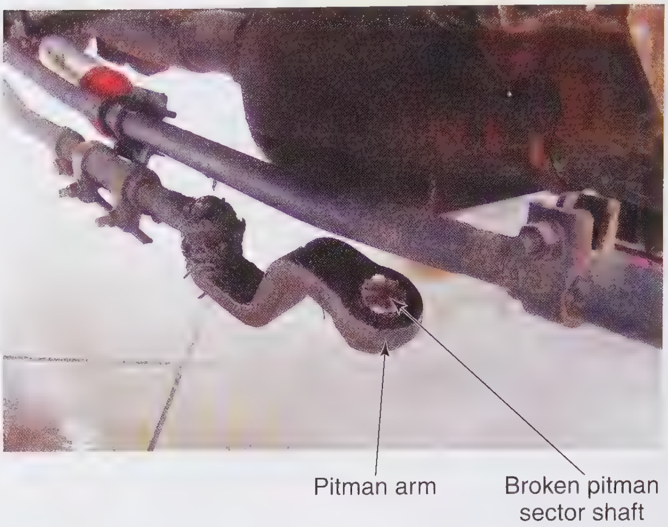


Figure 18-29. *An impact on the left front wheel as the steering wheel was turned caused the pitman sector shaft to break. The remains of the shaft can be seen in the pitman arm.*

The steering column can also be damaged in a collision. This is often the result of the driver contacting the column. A collapsed column will be shorter in length than an undamaged column.

An impact on a wheel can cause suspension system damage. Suspension damage can range from bends to breaks. Any suspension component can be damaged. A wheel that is not correctly positioned indicates suspension system damage. Obvious indications of suspension damage are shown in **Figure 18-30**. One exception to the out-of-place-wheel rule is that if a full frame vehicle is hit at the front, the frame may bend behind the front wheel, allowing the front wheel to move back. The suspension may not be damaged. Instead, the wheel is out of position because the frame has been moved rearward from the point where the front suspension is mounted.

Inspection

Care must be taken when diagnosing steering, suspension, and wheel assembly problems. Accurate diagnosis involves recognizing that a problem exists and identifying its cause. To diagnose a problem, gather as much information as possible.

A test drive can help identify suspension and steering system problems. If possible, drive the vehicle on a level road at moderate speed. Release the steering wheel

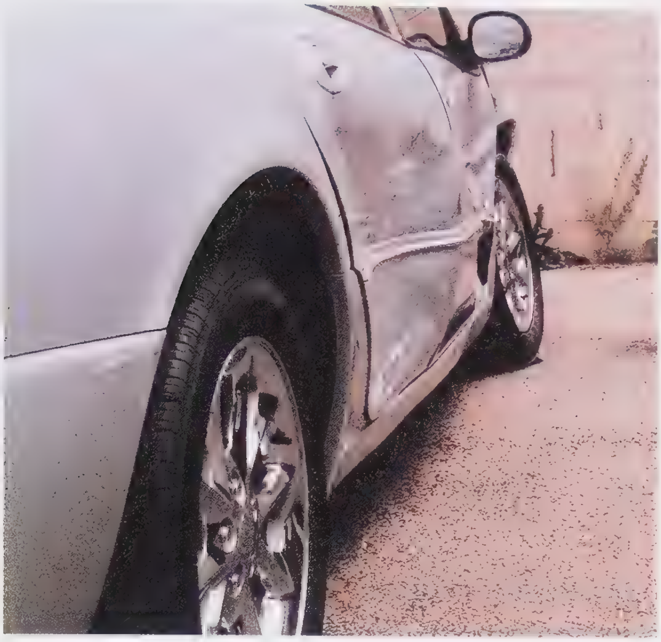


Figure 18-30. *The front wheel is pushed in at the top due to a collision.*

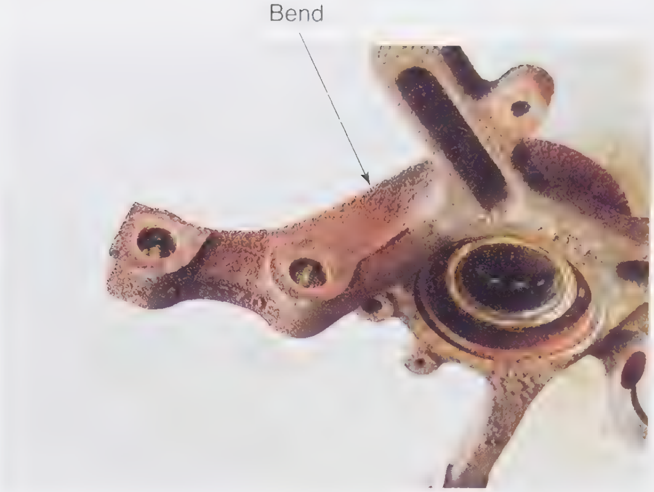


Figure 18-31. *The stress in the bend area will rearrange the rust pattern on suspension parts.*

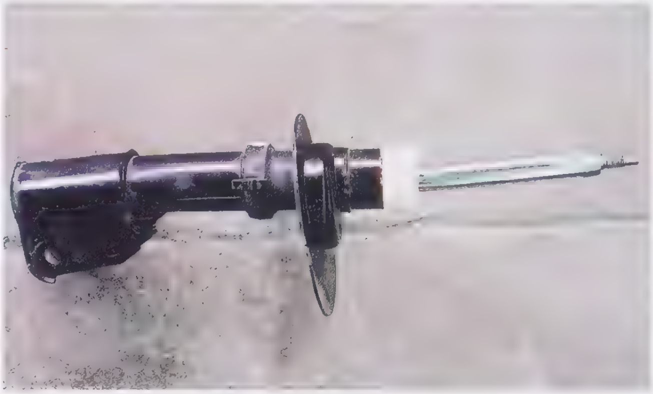


Figure 18-32. *An undamaged strut would be parallel to the line on the shop floor. Notice how this damaged strut is bent in two directions.*

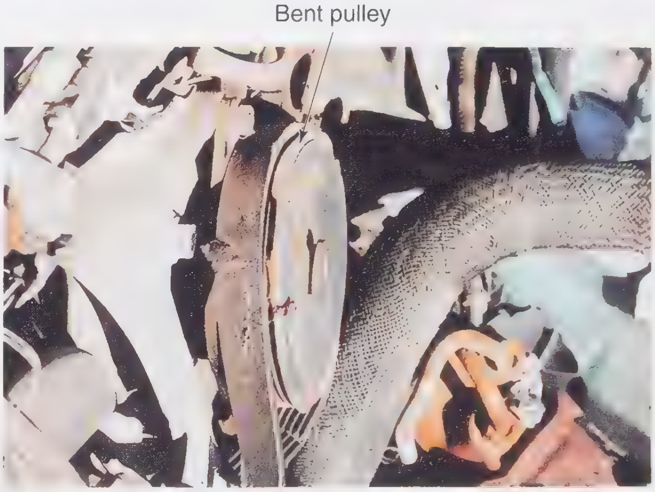


Figure 18-33. *This pulley damage is obvious. A slightly damaged pulley may not be so easily detected. A bent pulley will wobble when rotating.*

to determine if the vehicle drifts to one side. Collision damage can cause the vehicle to pull. While driving, take note of any unusual noises and vibrations.

Front-wheel-drive vehicles should be checked for torque steer. Torque steer means that under quick acceleration, the vehicle tries to straighten while turning or pull to one side when traveling straight ahead, especially when the transaxle shifts from first to second gear. A slight amount of torque steer is normal on some front-wheel-drive vehicles, primarily while turning. A broken engine mount, which causes the engine to sag on one side, will cause torque steer. Torque steer can also be caused by collision damage, such as misalignment or damage to the shock tower or steering knuckle.

After the test drive, perform a visual inspection of the vehicle. Bends in the steering or suspension components can be detected by careful observation. Suspension components may develop a coating of rust. An impact on a part will cause stress in the metal. This stress may rearrange the rust pattern on the part. This rust rearrangement may be visible as small lines. See **Figure 18-31**. The bend in the strut shown in **Figure 18-32** may not be obvious when the strut is installed on the vehicle, but it can easily be seen when checked with a straightedge.

Look for leaking fluid. The power steering reservoir may be located behind the radiator support. The reservoir can be damaged in a crash. The power steering pump pulley can also be damaged in a crash. A bent pulley will wobble as it turns. **Figure 18-33** shows a bent power steering pump pulley.

A few simple measurements can also be made to identify damage. A quick way to check for damage is to measure the vehicle's ride height. ***Ride height*** is the distance between a specified point on the vehicle and the shop floor. Ride height specifications can be found in an appropriate service manual. Before checking ride height, remove any heavy objects from the trunk or bed to get the vehicle as close to curb weight as possible. ***Curb weight*** is the weight of the vehicle without passengers or cargo, but with a full tank of gas, the engine full of oil, and the cooling system full of coolant.

Ride height measurements should be made on a level floor. **Figure 18-34** shows how measurements are made at the rocker panel. If one measurement is too high, then it is probable that the diagonally opposite measuring point is too low. Improper ride height may be caused by damage to suspension components.

Measuring ball joint position will also uncover suspension damage that was not evident during a visual inspection. See **Figure 18-35**. The vehicle shown had an impact on one wheel. Measurements are taken on each side of the vehicle from the ball joint to a reference point. If the measurements vary by more than 1/8", there is probably some type of suspension problem, such as a damaged strut, steering knuckle, or lower control arm.

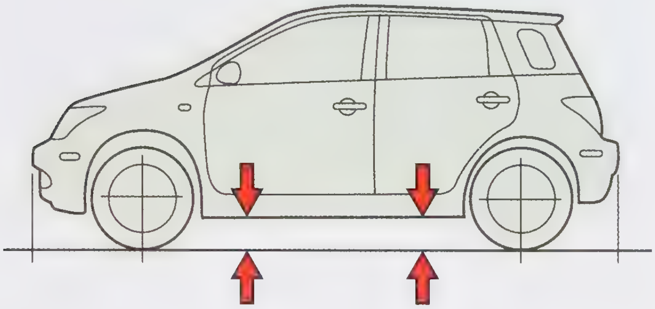


Figure 18-34. *Ride height measurements are taken between specific locations on the vehicle and the floor as indicated by the red arrows. The ride height measurements are compared to specifications.*

Figure 18-35. *Comparative measurements are a quick way to determine if suspension damage is present.*

Steering system damage can sometimes be identified by simply centering the steering wheel. First, turn the steering wheel all the way in one direction. Then, count the number of turns required to turn the steering wheel all the way back in the opposite direction. Divide this by two to determine the halfway point. Now, turn the steering wheel back to the halfway point using the calculated number of turns. If the steering wheel is not centered when the halfway point is reached, the steering gearbox or rack-and-pinion assembly may be damaged. If the front wheels do not point straight ahead when the halfway point is reached, the steering arm or steering linkage may be damaged.

Bump steer means that the wheels will steer independently of the steering wheel as the suspension travels up or down over bumps in the road. Bump steer is caused by out of level steering system components. In a rack-and-pinion steering system, the rack-and-pinion assembly, inner tie rods, and outer tie rods must be level. On a parallelogram steering system, the center link must be parallel to a level floor and the tie rods should be parallel to the lower control arms.

To check for bump steer, first center the steering wheel as described previously. Mark the top of the steering wheel with masking tape. Next, jounce the suspension by bouncing the vehicle. Push down on the front bumper several times, making the front of the vehicle bounce. While jouncing the suspension, watch the tape on the steering wheel. If the steering wheel rotates, even slightly, the vehicle has bump steer.

A simple test for a bent wheel is shown in **Figure 18-36**. Jack up the vehicle and support it on jack stands. Rotate the wheel while observing the distance between the wheel and a reference point. If the distance between the wheel and the reference point changes as the wheel spins, the wheel is bent. If the distance between the wheel and the reference point remains the same, the wheel is straight.

A bent axle or spindle can be detected in the same manner as a bent wheel. Jack up the vehicle, support it on jack stands, and remove the wheel. Set up a reference point and spin the brake drum or rotor. If the distance between the brake drum or rotor and the reference point changes as the drum or rotor spins, the axle or spindle is bent.

A bent strut may be obvious if the top of the wheel is leaning inward or outward. A leaking strut indicates damage or wear. Other strut damage can be detected with the method shown in **Figure 18-37**. Loosen, but do not remove, the locknut at the top of the strut. Rotate the strut shaft and watch the top of the tire. If the tire moves in and out as the shaft rotates, then the strut is bent. This technique will not work on all types of struts.

Another way to check for a bent strut on a vehicle with disc brakes requires an undamaged strut for comparison.

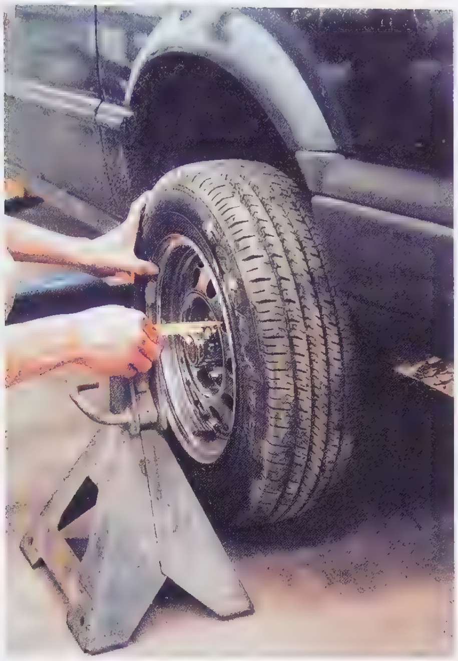


Figure 18-36. *The pencil serves as a reference point while turning the wheel. If the distance between the pencil and the wheel changes while the wheel is turned, the wheel is bent.*

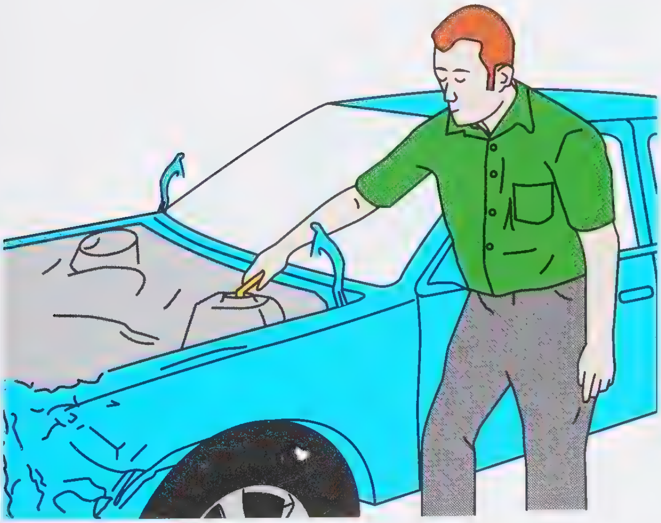


Figure 18-37. *A bent strut shaft will cause the wheel to move in and out as the shaft is rotated.*

To check a front strut, remove the tire and wheel from both sides of the vehicle. Place a straightedge on the brake rotor in such a way that it extends about 6" above the rotor. Measure the distance from the straightedge to the strut. Make the same measurement on the undamaged side of the vehicle. A difference in these measurements indicates damage.

Wheelbase is the distance between the center of the front wheel and the center of the rear wheel. ***Tracking*** is the ability of the vehicle's rear wheels to track directly behind the front wheels. Checking wheelbase and tracking requires two technicians. These checks are crude, but they are useful to identify suspension damage or frame misalignment.

To begin, make sure the front wheels are pointed straight ahead. Measure wheelbase with a tape measure stretched from the front edge of the rear wheel and the front edge of the front wheel. Compare the measurements on each side to the factory specifications. If the measurements are not the same side to side or deviate from the specification, suspect frame damage, a misaligned engine cradle, a bent wheel, a damaged lower control arm, or a misaligned rear axle assembly.

If the wheelbase is correct, check tracking. This test will determine if the rear wheels travel directly behind the front wheels. If the engine cradle is shifted to one side, the rear wheels will not follow directly behind the front wheels. A misaligned rear axle assembly or improper toe on a rear wheel will also cause tracking problems. If the rear wheels are not perpendicular to the centerline of the vehicle on a vehicle with a solid rear axle, the rear wheels will track the vehicle toward the side to which the rear wheels are pointing. See **Figure 18-38**. If the rear wheels are independent and not connected by an axle, the rear wheels still determine the track of the vehicle, even if only one wheel is out of specification.

Mount the vehicle on turntables and leave the ignition key in the *on* position to unlock the steering wheel. Turntables are used in wheel alignments and allow the wheels to move. The turntables will indicate the angle to which each wheel is steered.

Use a piece of string that will span the length of the vehicle. Starting on one side of the vehicle, ask a helper

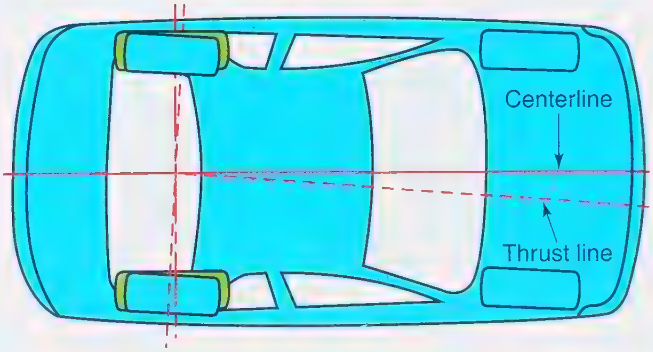


Figure 18-38. *If the rear wheels are not perpendicular to the centerline, they will not track properly. Instead, they will track the vehicle toward the side to which the rear wheels are pointing. On this vehicle, the rear wheels are tilted toward the right.*

to hold the string level with the center of the wheel at the rear edge of the rear tire. Try to steer the front wheels so the string will touch the front and rear edges of the front tire. If this can be done, measure the distance between the front edge of the rear tire and the string. Check the other side of the vehicle in the same way. If these measurements are the same, there is no misalignment. If the measurements are not the same, there is damage present. On vehicles with a damaged front end, suspect misalignment of the engine cradle. On vehicles with a damaged back end, suspect misalignment of the rear axle assembly or a rear wheel.

If the wheels cannot be steered so that the string touches the front and rear of the front tire but the string touches the front and rear of the rear tire, measure the distance between the string and the rear edge of the front wheel. Measure the other side in the same way. A difference in the measurements indicates the above referenced misalignments.

Steering and Suspension System Repair

The following section highlights the service and repair procedures commonly performed by the collision repair technician. The operations are generic in nature and may not apply to the specific vehicle being repaired. Consult a repair manual for recommended procedures and torque values for the specific vehicle being serviced. All these operations begin with safely raising the vehicle with a floor jack or a lift. If the vehicle is raised with a floor jack, it must be supported on jack stands. The wheels may be removed for some operations.

Used suspension parts may be specified for some repairs. One criterion used to determine if used parts will be acceptable for a repair is the mileage on the parts vehicle. If the damaged vehicle has more miles on it than the parts vehicle, the used parts should have less wear on them than the damaged parts and, therefore, are acceptable replacements. However, any part that is subject to wear should be replaced with a new part.

Some parts that are subject to wear, such as MacPherson struts and springs, should be replaced as a pair. For example, if the left front strut is replaced, the right front strut should also be replaced so performance of both front struts is the same. If one strut is new and the other is worn, the vehicle's left and right sides will not respond to road shocks in the same way, and the vehicle could be difficult to handle.

Fasteners may be locked in place by rust and corrosion. There are three ways to free rusted fasteners: lubrication, vibration, and heat. Lubrication involves spraying the fastener with penetrating oil. The penetrating oil may be able to seep between the threads to free the rusted fasteners. To use this method, spray the joint between the nut and bolt. Allow plenty of time for the oil to work, overnight if possible.

Vibration can also be used to break the rust bond between a nut and a bolt. Place the cutting end of an air chisel on the nut. The intent is not to cut the nut off but to vibrate it. Pull the air chisel's trigger and release it. Vibrate the nut several times before removing the fasteners.

The third method to free rusted fasteners is to use heat. Heating a nut will cause it to expand, breaking the corrosion bond. Before heating a nut, make sure there are no combustible materials nearby. Using an oxyacetylene torch set to a neutral flame, heat the nut uniformly by circling around the nut. Stop when the nut turns red. Allow the nut to cool before trying to turn it. Do not use heat on any component that will be reused. Heat may destroy the strength of the component. If a component has been heated, replace it!

NOTE

Some steering and suspension nuts or bolts cannot be reused. These are called single-use or torque-to-yield fasteners. When removed, these fasteners lose their strength. The vehicle repair manual will identify single-use fasteners.

Replacing an Outer Tie Rod (Tie Rod End)

Outer tie rods, or tie rod ends, are the connection between the steering knuckle and the adjusting sleeve of the inner tie rod on rack-and-pinion steering systems or the inner tie rod, center link, or drag link on parallelogram steering systems. The tie rod end's tapered stud fits into a hole in the steering arm. The stud is held in place with a castellated nut. A threaded shaft connects the tie rod end to the adjusting sleeve. Tie rod ends are subject to wear or collision damage.

Worn or damaged tie rod ends are replaced by first counting the number of threads visible on the tie rod shaft. When the new tie rod end is installed with the same number of threads visible, the toe-in alignment will be approximately correct.

Next, separate the tie rod end from the steering arm on the knuckle. There are two methods to separate the tapered stud from the steering arm. Both methods require the removal of the cotter pin and the nut. To follow the first method, use a hammer to tap on the steering arm as shown in **Figure 18-39**. The tapping will eventually cause the tapered stud to slide out of the arm. The second method involves using a puller to apply pressure to the tapered stud to force it out of the hole in the steering arm.

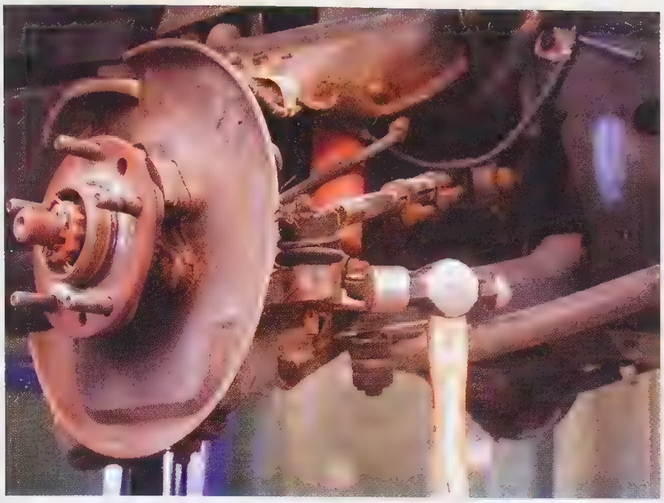


Figure 18-39. *Hammering on the steering arm will help loosen the tie rod end. Some technicians recommend holding a large hammer against the opposite end of the steering arm to concentrate the force of the hammer blows.*

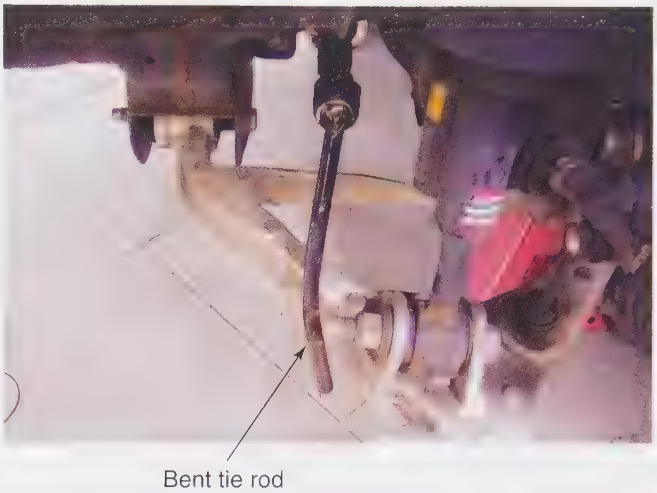


Figure 18-40. *The long socket used to remove the rack-and-pinion nut will not fit over a bent tie rod. Cut the tie rod to allow the tool to fit.*

Once the tapered stud is separated from the steering arm, rotate the tie rod end to remove the tie rod shaft from the adjusting sleeve. Install the new tie rod end by turning the tie rod shaft into the adjusting sleeve until the specified number of threads are visible. Slip the tapered stud into the hole in the steering arm. The fit should be very tight. Install the castellated nut, tighten it to specifications, and install a new cotter pin. The cotter pin slips into a slot in the tie rod end stud and through the slots in the castellated nut. If the slots on the tie rod and nut do not align, tighten the nut until they do. Never loosen the nut to align the slots. Bend the legs of the cotter pin to hold it in place. After tie rod replacement, the vehicle will need a front end alignment.

Replacing an Inner Tie Rod

Inner tie rods on rack-and-pinion steering systems may be damaged by a front or side impact on a front wheel. The lower control arm, strut, steering knuckle, tie rod end, and rack-and-pinion assembly may also be damaged. A bent inner tie rod must be replaced. Begin by removing the tie rod end from the steering arm as described in the previous section. The tool used to turn the nut at the rack will not fit over a bent tie rod. If the tie rod is bent as shown in **Figure 18-40**, cut it off with a cut-off wheel or plasma cutter. With the bent rod cut off, the tool can be used to reach the nut at the rack. Remove the bellows at the rack-and-pinion assembly and slide it out of the way. Loosen the nut at the rack with the tool and remove the inner tie rod. Install the bellows on the new inner tie rod and thread the tie rod into place. Tighten the nut to the proper torque and install the bellows on the rack-and-pinion housing. Install the tie rod end as described above. The vehicle will need a front end alignment after inner tie rod replacement.

Replacing a Center Link

On a parallelogram steering system, the center link and tie rods are connected with studs and nuts. This is similar to the way a tie rod end is fastened to a steering knuckle. To remove a center link, first remove the cotter pins, then remove the nuts at the pitman arm, idler arm, and tie rods. Tapping on the center link with a hammer should loosen the studs. Placing a large hammer on the opposite side of the stud will concentrate the force of the striking hammer by preventing the stud from moving.

Install the new center link by sliding the studs in the pitman arm, idler arm, and tie rods through the holes in the center link. Install the nuts on the studs and torque them to the specified value. Install cotter pins as needed.

To remove a tie rod in a parallelogram system, disconnect the tie rod from the center link as described above. The tie rod end is threaded onto the end of the tie rod. Count the number of threads visible on the tie rod where the tie rod end is attached. Loosen the locknut on the tie rod end and thread the tie rod off the tie rod end. Thread the new tie rod onto the tie rod end. Turn the tie rod in until the same number of threads are visible as before removing the tie rod. Slip the tie rod stud into the hole in the center link. Install and torque the nut to the specified value. If slots in the nut and stud do not line up, tighten the nut until the slots line up. Tighten the locknut at the tie rod end. Install cotter pins as required. After the new tie rod is installed, the vehicle should be aligned.

NOTE

Many steering and suspension fasteners must be installed to a specified torque. A torque wrench is used to install these fasteners.

Replacing a Rack-and-Pinion Gearbox

An impact on a wheel, especially a severe side impact, may break the rack in a rack-and-pinion gearbox. Turning the steering wheel will cause binding as the broken rack moves over the pinion. The rack-and-pinion housing can also be cracked and leaking.

To remove a power rack-and-pinion gearbox, disconnect the power steering lines, if necessary. Place a pan under the vehicle to collect the dripping power steering fluid.

Disconnect the tie rod ends from the steering knuckles and unbolt the steering linkage from the rack. Unbolt the rack-and-pinion assembly from the unibody or engine cradle, and pull the assembly from the vehicle.

To install a new rack-and-pinion assembly, slide the assembly in place so it aligns with the steering linkage. Then, bolt the assembly in place. Next, install the bolt for the steering column, install the tie rods, and tighten all bolts to the proper torque. If necessary, reinstall the power steering lines and fill the power steering reservoir.

To function properly, the rack-and-pinion assembly must be level. An out-of-level assembly causes bump steer.

Replacing a Parallelogram Steering Gearbox

An impact on one or both front wheels may cause a twist in the steering shaft. A severe impact may break the parallelogram steering gearbox housing, allowing power steering fluid to leak.

To remove a parallelogram steering gearbox, take off the nut securing the pitman arm and remove the pitman arm from the gearbox with a puller. Unbolt the steering linkage and then disconnect the power steering lines, if necessary. Unbolt the gearbox from the frame. Be careful, as the gearbox is heavy. Install the new gearbox by bolting it in place.

The output shaft has external splines, and the pitman arm has internal splines. The pitman arm must be properly aligned with the gearbox output shaft. Both the output shaft and the pitman arm are splined. The pitman arm has a raised rectangular section in the splines, and the output shaft has a matching rectangular slot. These two are called the indexing splines and aid in lining up the pitman arm to the output shaft. Position the pitman arm so the indexing splines line up. Tap the pitman arm into position on the output shaft with a soft-faced hammer. When the threads on the output shaft are visible, install the nut to force the pitman arm into place. Torque the nut to the specified value. Finally, install the steering linkage and, if necessary, the power steering hoses.

Replacing a MacPherson Strut

An impact on a wheel may move the wheel and bend the strut. A bent strut must be replaced. Begin by supporting the assembly that will be removed. Remove the nuts that secure the strut to the steering knuckle and then drive out the bolts. Next, remove the nuts at the strut tower. If necessary, remove any bolts or clips used to secure the brake line to the strut. Finally, remove the strut assembly from the vehicle.

Loosen the top nut on the strut assembly one turn. Mount the assembly in a strut spring compressor, compress the spring, and remove the nut. Remove the bearing, seal, and washers, noting the order in which they should be reinstalled. Assemble the bearing, seal, washers, and spring on the new strut. Install the top nut, tighten it to the proper torque, and release the spring. Install the strut assembly on the vehicle. Slide the bolts into the strut and steering knuckle, and install the nuts on the bolts and at the strut tower. **Figure 18-41** shows one type of strut spring compressor in use.

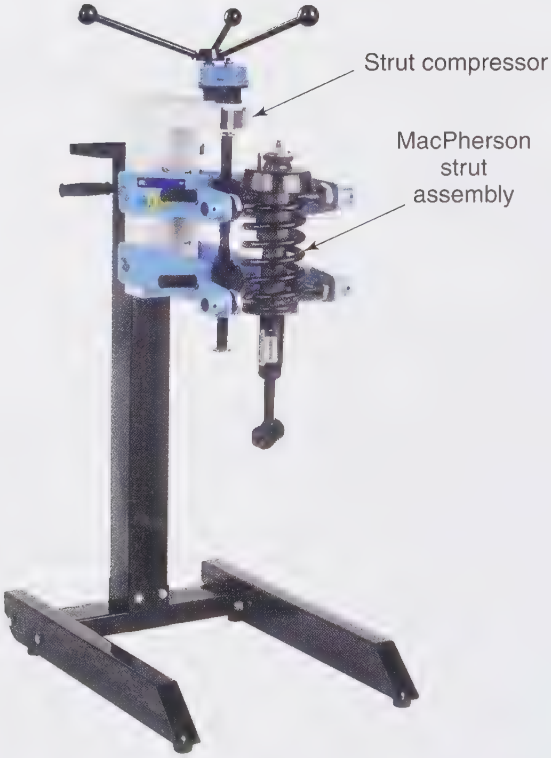


Figure 18-41. *MacPherson strut assembly mounted in a spring compressor. The spring must be compressed when replacing the strut. (OTC)*

NOTE

The nuts holding a shock absorber or strut in place at the top are easily removed with an impact wrench. The problem with using a hand wrench or ratchet to turn the nut is that the shaft on which the nut is mounted turns also. The impact wrench turns the nut faster than the shaft can turn, so the nut comes off.

Replacing a Modified MacPherson Strut

To remove a modified MacPherson strut, begin by compressing the coil spring before the strut is removed. An internal spring compressor fitted inside the coil spring will contain the potential energy of the spring. This type of spring compressor has two sets of arms that grab the spring. One set of arms is positioned near the top of the spring and the other set is positioned near the bottom. Tightening the bolt draws the sets of arms together, compressing the spring. See **Figure 18-42**. Avoid nicking the paint on the spring. Unprotected springs will rust and weaken.

WARNING

Use extreme care when removing the coil spring. The coil spring contains potential energy and can shoot from the vehicle with deadly force if the spring compressor is not installed properly.

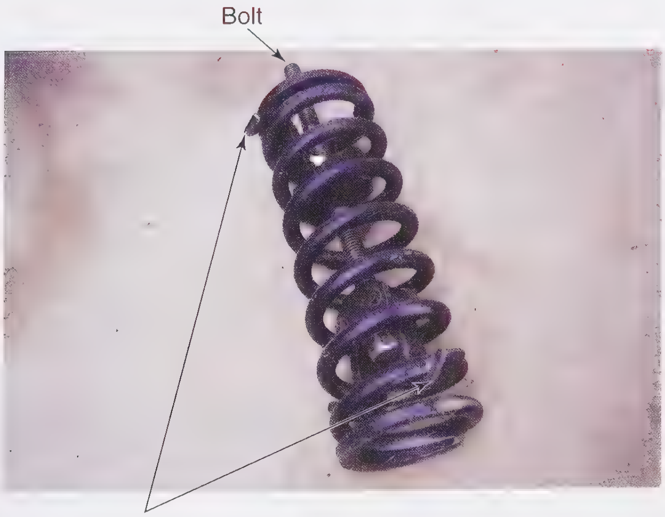


Figure 18-42. *An internal spring compressor has two arms to grab the coils of the spring. Tightening the threaded rod brings the arms together, compressing the spring.*

After compressing the spring, remove the nuts from the strut bolts at the steering knuckle or spindle. The bolts may need to be driven out. Remove the nuts at the strut tower and remove the strut. The lower control arm will drop down and the compressed spring will slide out of position.

To install the new strut, slip the strut into the bolt holes in the strut tower and install the nuts. Align the compressed spring and raise the lower control arm. Position the bottom of the strut at the steering knuckle or spindle, and install the bolts and nuts. Torque all the fasteners to the specified value.

Replacing a Coil Spring—Short/Long Arm Suspension

A coil spring in a short/long arm suspension system is under tremendous tension. If the spring is improperly removed, it can uncoil with enough energy to shoot across the shop. This could easily injure or kill anyone in the way.

A spring compressor must be used to remove a coil spring on a short/long arm suspension. All spring compressors work in the same way. The compressor attaches to the top and bottom of the spring. It is tightened to draw the top and bottom of the spring together, shortening the spring and allowing it to be safely removed from the vehicle.

Install the compressor on the spring and tighten it to compress the spring. Remove the shock absorber and disconnect the lower control arm at the ball joint. The lower control arm will move down far enough to allow the compressed spring to be removed. After removing the spring, slowly release the spring from the compressor.

To install a new spring, compress it with the spring compressor. Be careful not to nick the finish on the spring. Install the compressed spring. Then reinstall the ball joint and shock absorber. Finally, release the spring compressor.

Replacing a Coil Spring—Solid Rear Axle

To remove a coil spring from a solid rear axle, jack up the vehicle and place it on jack stands. Position a floor jack under the axle and the coil spring. Raise the floor jack to compress the spring. Disconnect the shock absorber and trailing arm (if required). Lower the floor jack slowly to release the tension on the spring. To install the new spring, position the spring in the spring mount. Carefully jack up the rear axle under the spring to compress the spring. Install the shock and, if required, the trailing arm. Finally, tighten the fasteners to the specified torque.

Replacing a Control Arm

A wheel that is not correctly positioned in the wheel opening may be an indication of a bent lower control arm. A bent control arm must be replaced.

Begin by supporting the suspension at the wheel being serviced. On short/long arm suspension vehicles, the spring must be compressed before the control arm can be removed. A modified strut suspension may have the spring mounted on the lower control arm rather than around the strut. In this type of suspension, the spring will also need to be compressed. On conventional MacPherson strut suspensions, compressing the spring is not necessary. After compressing and securing the spring (if needed), disconnect the lower ball joint and remove the bolts holding the control arm to the vehicle's unibody or frame. **Figure 18-43** shows a control arm replacement in progress. After the steering knuckle and coil spring have been removed, install bushings as needed and position the new control arm on the unibody or frame. Slide the bolts in place and install the nuts. Insert the ball joint stud into the steering knuckle and install the nut. Finally, tighten all fasteners to the specified torque.

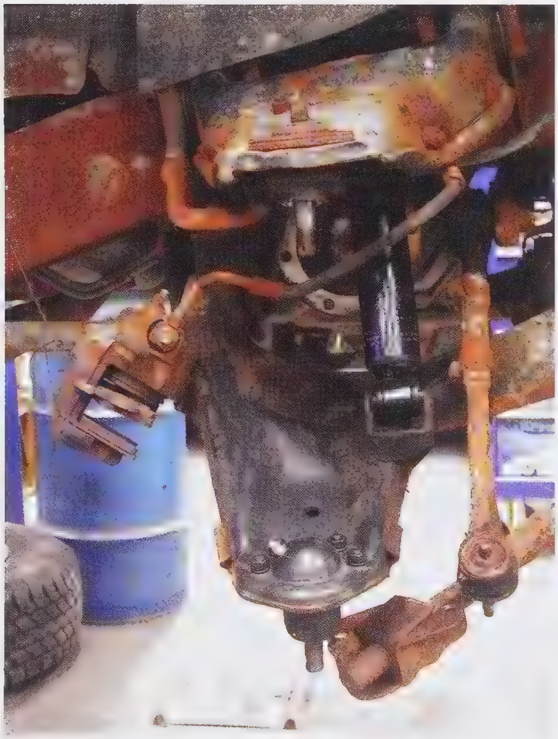


Figure 18-43. *This four-wheel-drive SUV required the removal of the drive axle, brake rotor, caliper, tie rod end, stabilizer bar, steering knuckle, coil spring, and shock absorber for lower control arm replacement. Note that the ball joints remain on the upper and lower control arms.*

Replacing a Steering Knuckle

To remove a steering knuckle in a MacPherson strut front suspension, begin by removing the brake caliper. Use a wire to hold the caliper out of the way so there is no weight on the brake line. Remove the brake rotor and the nut from the CV axle. Disconnect the ball joint. Remove the nuts at the base of the MacPherson strut and drive out the bolts. Slide the steering knuckle off the half shaft. Wire the half shaft up so it does not hang from the transaxle.

Before reassembly, a new bearing may have to be pressed in place on the new knuckle. Next, slide the CV axle into the splines in the new knuckle. Slip the ball joint stud into place on the knuckle, and install the strut and strut bolts. Install and torque all the nuts. Install the rotor and bolt the caliper in place.

To replace the steering knuckle on an SLA suspension with tapered roller bearings, remove the brake caliper and wire it out of the way. Then, remove the grease cap, locknut, and adjusting nut. Slide the rotor off the spindle. Be careful of the wheel bearings. The outer wheel bearing will slide off with the hub. The inner wheel bearing may stay on the spindle. Disconnect the tie rod end from the steering arm. Use a spring compressor to compress the coil spring. Then, remove the upper and lower ball joints from the steering knuckle and remove the knuckle.

To replace the steering knuckle, first position it on the upper and lower ball joint studs. Install the nuts. Attach the tie rod end and install new seals on the rotor. Slide the inner wheel bearing in place, then the rotor, and finally, the outer wheel bearing. Set wheel bearing preload. Install the caliper.

NOTE

The procedure for servicing wheel bearings is detailed later in this chapter.

Replacing a Leaf Spring

A rear impact on a vehicle with leaf springs may overarch a leaf spring, requiring spring replacement. An impact on a rear wheel may also damage a leaf spring by bending, twisting, or breaking the spring or the mount. See **Figure 18-44**.

To remove and replace a leaf spring, raise the vehicle and support it by the frame. Support the rear axle housing with jack stands. Unbolt the shock absorber. Remove the nuts on the U-bolts and the nuts on the spring shackle bolts. Drive out the spring shackle bolts. Remove the spring. You may have to install bushings in the spring eyes of the new spring. Then, position the new spring in the shackle. Install the bolts and nuts. Finally, install the U-bolts and nuts, followed by the shock absorber.

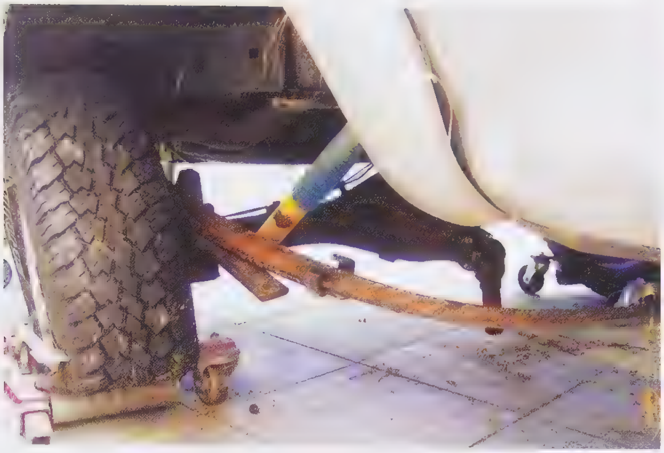


Figure 18-44. *An impact on the right rear wheel caused this rear axle housing to shift location on the leaf springs. The leaves of the spring have been separated by the rearward movement of the axle housing.*

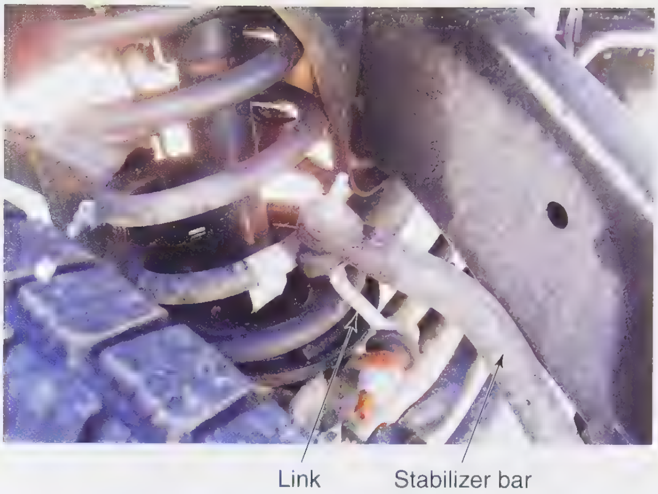


Figure 18-45. *This stabilizer bar link is broken. A front impact on the right frame rail caused the rail to move back. The stabilizer bar, mounted on the frame, moved back also and caused the link to bend. Notice that the stabilizer bar end and link are jammed against the spring.*

Replacing a Stabilizer Bar and Links

Stabilizer bar links connect the stabilizer bar to the lower control arms. The links are the weakest part of the stabilizer bar assembly. Stabilizer bars occasionally bend or break, but it is more common for the links to be damaged. See **Figure 18-45**. If the stabilizer bar or links need to be replaced, other suspension parts, such as the lower control arm, generally need to be replaced also.

Stabilizer bar links consist of nuts, threaded metal studs, and rubber bushings. To remove a stabilizer bar link, loosen the nuts. If the damage caused by bending prevents easy access, cut through the link with a cutoff tool for easier access. If the stabilizer bar must be removed, remove the links at either end and then unbolt the stabilizer bar from the frame. To reinstall a stabilizer bar and link, first bolt the stabilizer bar to the frame. Then, assemble the links with the bushings in the correct locations. Finally, install the links and torque all fasteners to the specified torque.

Removing and Installing a Steering Column

During a collision, a vehicle's driver may be thrown forward, striking the steering wheel and causing the steering column to collapse. A collapsed steering column must be replaced. The steering column may also need to be removed and reinstalled during dash removal. Some manufacturers recommend checking and replacing a steering column after air bag deployment.

To remove the steering column, begin by disconnecting the battery. Following the manufacturer's instructions for air bag removal, remove the driver's side air bag. If both air bags are deployed, the air bag in the steering wheel can be unbolted after the battery is disconnected. From under the hood, unbolt the steering shaft from the coupler.

NOTE

Air bag replacement will be covered in a later chapter.

Inside the vehicle, remove the upper and lower plastic shrouds from around the steering column. Disconnect any electrical connectors from the column. Locate and remove the boot that seals the opening in the cowl the steering shaft passes through. Then, unbolt the steering column from the under-dash support. There are usually four bolts holding the steering column to the support. Finally, pull the steering column out from under the dash.

To install a steering column, slide the column into place so the steering shaft passes through the hole in the cowl and aligns with the coupling under the hood. Bolt the steering column to the support, install the boot, hook up the electrical connectors, and install the plastic shrouds. From under the hood, bolt the steering shaft to the coupler. Tighten all fasteners to the specified torque value.

Wheel and Tire Service

An impact on the wheel can damage both the tire and the wheel. See **Figure 18-46**. An impact on a wheel can also damage the hub, spindle, or steering knuckle. Do not attempt to straighten a damaged hub, spindle, or steering knuckle. These components are not repairable. If a hub, spindle, or steering knuckle is damaged, it must be replaced.

Servicing Tapered Roller Bearing Wheel Bearings

Parts such as seals or wheel bearings may be tightly fitted in place. To remove these parts, special tools may be required. When removing a seal, work around the seal rather than prying from one position only.

A bearing race may be driven out with a punch. Work all areas of the race to drive it out instead of tapping in just one place. To install a race or seal, use an appropriate driver, **Figure 18-47**. Tapping on the driver spreads the force evenly over the component being installed. The race or seal must be inserted squarely in its bore. Tilting of the race or seal during installation will cause binding and may prevent proper installation. A press can also be used to install a race or seal.

Tapered wheel bearings should be inspected and packed whenever suspension disassembly exposes them. Use clean solvent to clean wheel bearings. Hardened grease can be removed by scrubbing with a brush. Clean the inside of the hub also. Dry the parts with lint-free towels.

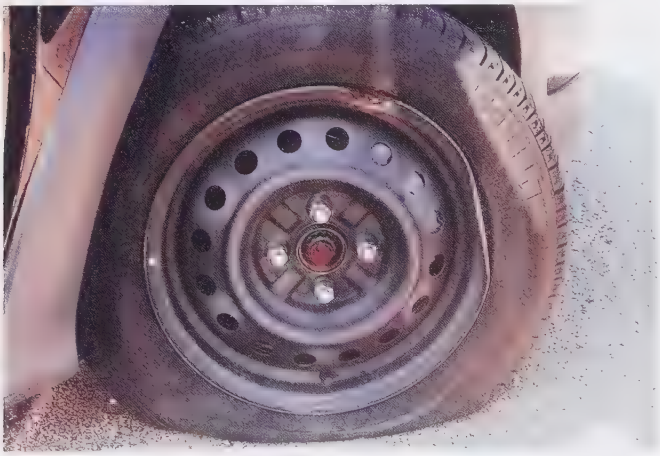


Figure 18-46. *The wheel is bent in two places and the tire is flat.*

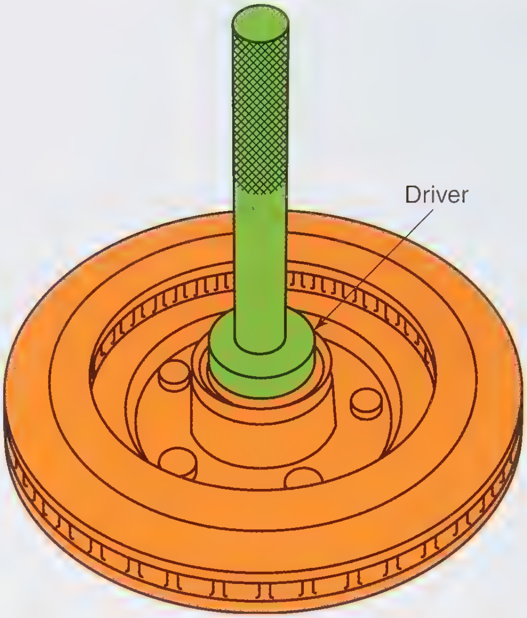


Figure 18-47. *The new bearing race must be evenly tapped into the hub. The proper driver makes the job easy.*

Before bearings are installed, they must be packed with grease. Place wheel bearing grease in the palm of your hand and press the wide end of the bearing into the grease. This forces the grease around the roller bearings. Make sure each roller bearing is surrounded by grease. Also, apply a light coat of wheel bearing grease to all surfaces that the wheel bearing will touch.

Wheel bearing preload is used to set tapered wheel bearings in place. To set preload, install the wheel bearings and hub on the spindle. While rotating the hub, tighten the adjusting nut to the specified torque. This sets the bearings. Then, loosen the nut just enough that the castellated locknut slots align with the hole in the spindle. This allows the cotter pin to slide in place.

Removing and Installing Sealed Wheel Bearings

Sealed wheel bearings cannot be serviced. If damaged or worn, they must be replaced. Wheel bearings on front-wheel-drive vehicles may be pressed into place in the steering knuckle or bolt-on hub. On some front-wheel-drive vehicles, the bolt-on hub and the wheel bearing are one part and must be replaced as a unit.

Replacing a damaged steering knuckle may require wheel bearing installation. The new steering knuckle should be placed in a press. The press is used to push in the new bearing. When using a press, make sure the new bearing is positioned squarely, otherwise binding and damage to the bearing or steering knuckle may result.

If the bearing is pressed into a bolt-on hub, the hub must be removed from the steering knuckle for bearing replacement. A press is used to remove the old bearing and install the new one in the hub. If the bearing and hub are one part, the damaged or worn hub and bearing are unbolted from the steering knuckle. The new hub and bearing are bolted in place.

Removing and Installing a Tire

Tires can be damaged by a collision impact. The only tire damage that is repairable is a small hole in the tread area of a tire that causes the tire to go flat. Occasionally, vegetation, such as grass or branches, is forced between the tire and the wheel as a vehicle skids off the road. See **Figure 18-48**. The material can be removed by removing the tire from the wheel, cleaning off the debris, and remounting the tire.

If a wheel is bent, the tire likely sustained enough force to damage it. Even if the wheel is not bent, the tire may be damaged. Inspect the tire for cuts in the tread and sidewall. Feel the inner and outer sidewalls of the tire for lumps or bulges that indicate damage to the belts. Replace any tire that has cuts, lumps, or bulges.

Check the inside of the tire after the tire is removed from the wheel. Rubber crumbs inside the tire indicate irreparable damage. Also look and feel for lumps, cuts, or bulges inside the tire. If the bead is cut, the tire must be replaced.

A tire machine is used to remove and install tires. See **Figure 18-49**. To remove a tire from the wheel, bolt the wheel down to the machine and let the air out of the tire by removing the core from the tire valve stem. Next, use the machine's plunger to press down on the tire adjacent to the rim to "break" the bead. If the wheel is equipped with a tire pressure sensor, avoid breaking the bead in the area of the sensor.

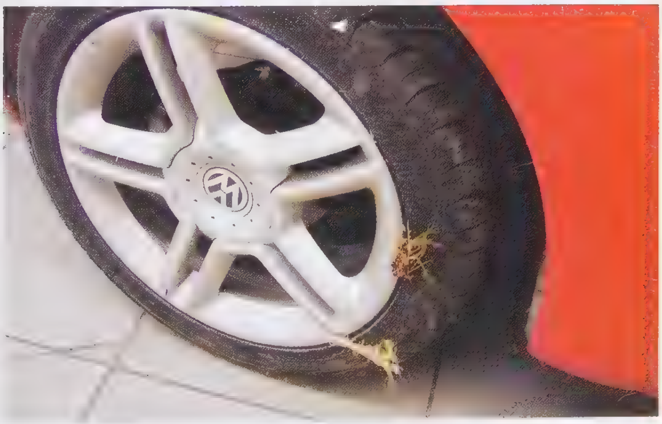


Figure 18-48. *This car ran off the road. The force of the collision caused these pieces of cornstalk to lodge between the tire and wheel.*

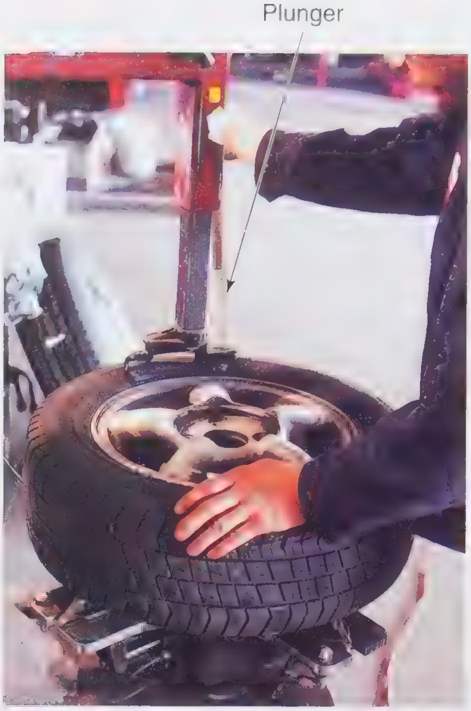


Figure 18-49. *The plunger on the tire machine presses down with enough force to break the bead loose from the rim.*

After breaking the bead, insert a bead tool under the upper bead. The bead tool will rotate to pull the bead from the wheel. After removing the upper bead, remove the lower bead from the wheel in the same way.

When a tire is installed on a wheel, the tire valve stem is usually replaced. After replacing the valve stem, position the wheel on the tire machine and place the tire on top of it. Apply lubricant on the bead. The lubricant allows the bead of the tire to slip into place on the rim. Use the bead tool to slip the lower bead over the wheel. Once the lower bead is installed, the upper bead can be slipped into place.

Inflate the tire to maximum air pressure listed on its sidewall, and then release air from the tire to the vehicle manufacturer's specified air pressure. This will firmly seat the bead on the rim.

WORKING GREEN

Always inflate tires to the pressure recommended by the vehicle manufacturer, not to the pressure specifications on the side of the tire. The pressure specification on the side of the tire is the maximum pressure the tire can handle at a specific load and speed. It is not the pressure that will provide best ride quality. A properly inflated tire also improves fuel economy and increases the life of the tire.

Balancing a Tire and Wheel

An unbalanced wheel and tire assembly will vibrate as it rotates. To prevent vibration, the tire and wheel assembly must be balanced. Balancing involves the use of wheel weights to equalize the mass all around the wheel and tire assembly. Vibration is caused by up-and-down motion and/or side-to-side motion of the spinning tire. Both up-and-down and side-to-side motion can be caused by a nonuniform tire shape.

Tires are made to specifications within a range of tolerances. A tire that is within the specified tolerance may still not be uniform enough to spin without vibration. Up-and-down motion is due to radial runout. Radial runout is caused by a tire that is not uniform in diameter. Side-to-side motion, or wobble, is caused by lateral runout. Lateral runout is caused by variation in the width of the tire. During balancing, weights are strategically placed to cancel the vibration from radial and/or lateral runout.

Balancing must be done each time a tire is installed on a wheel. A computerized balancing machine is shown in **Figure 18-50**. This machine spins the tire and wheel at a specified speed. The machine senses an imbalance and indicates where the wheel weights should be placed to equalize the weight of the tire and wheel assembly.

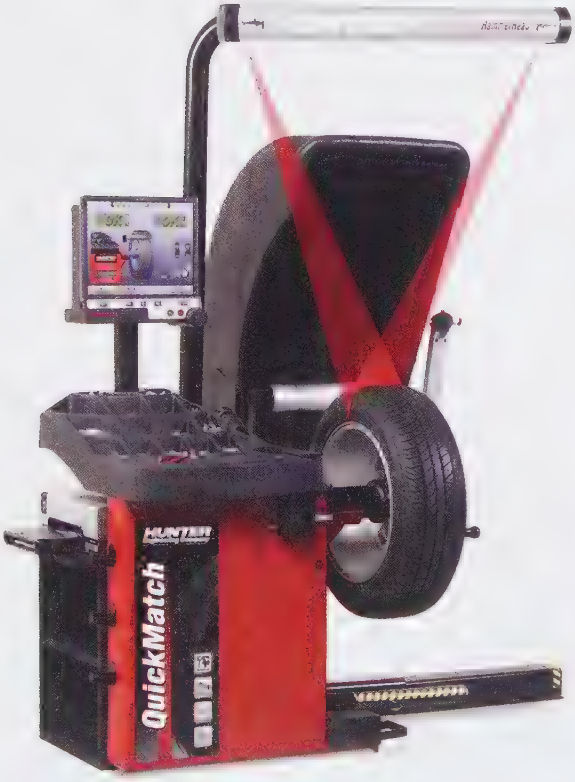


Figure 18-50. *This tire balancing machine spins the tire to determine where to position balancing weights. The lasers indicate where the weights should be installed. (Hunter)*

Wheel weights are available in different sizes to allow precise balancing. Wheel weights can clip onto the wheel or be adhesive backed. If the design of the wheel is such that it cannot accept clip-on weights on the front edge of the wheel, adhesive weights can be placed on the rear edge of the wheel.

NOTE

Some wheels may be installed on the vehicle with a locking lug nut. This lug nut has a unique configuration. An example is shown in Figure 18-51. A special socket that matches the locking lug nut's configuration must be used to remove this lug nut. This socket is generally stored in the vehicle's glove compartment.

Alignment

Wheel alignment must often be checked and adjusted when a steering or suspension part is replaced. A ***wheel alignment*** involves checking the suspension parts for damage or wear, measuring alignment angles, and setting all adjustable angles to specifications. This way, the vehicle will drive straight with a minimum amount of tire wear.

Rear-wheel-drive vehicles with a solid rear axle have no provision for alignment adjustments at the rear wheels. Therefore, a rear-wheel-drive vehicle with a solid rear axle is given a front-end alignment or a thrust-angle alignment. A ***front-end alignment*** checks and sets the front wheels only. A ***thrust-angle alignment***

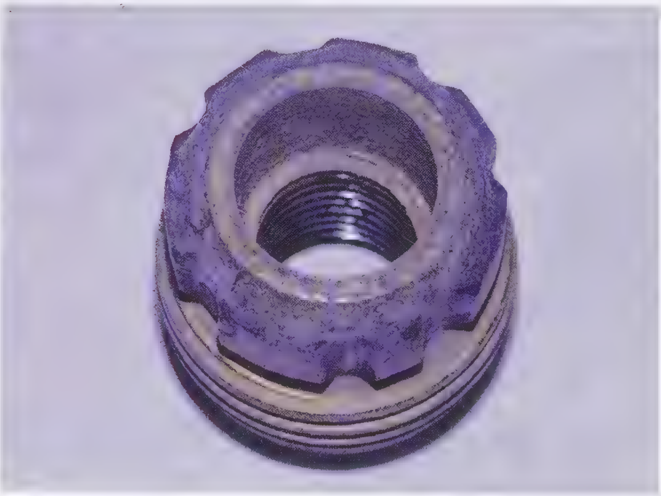


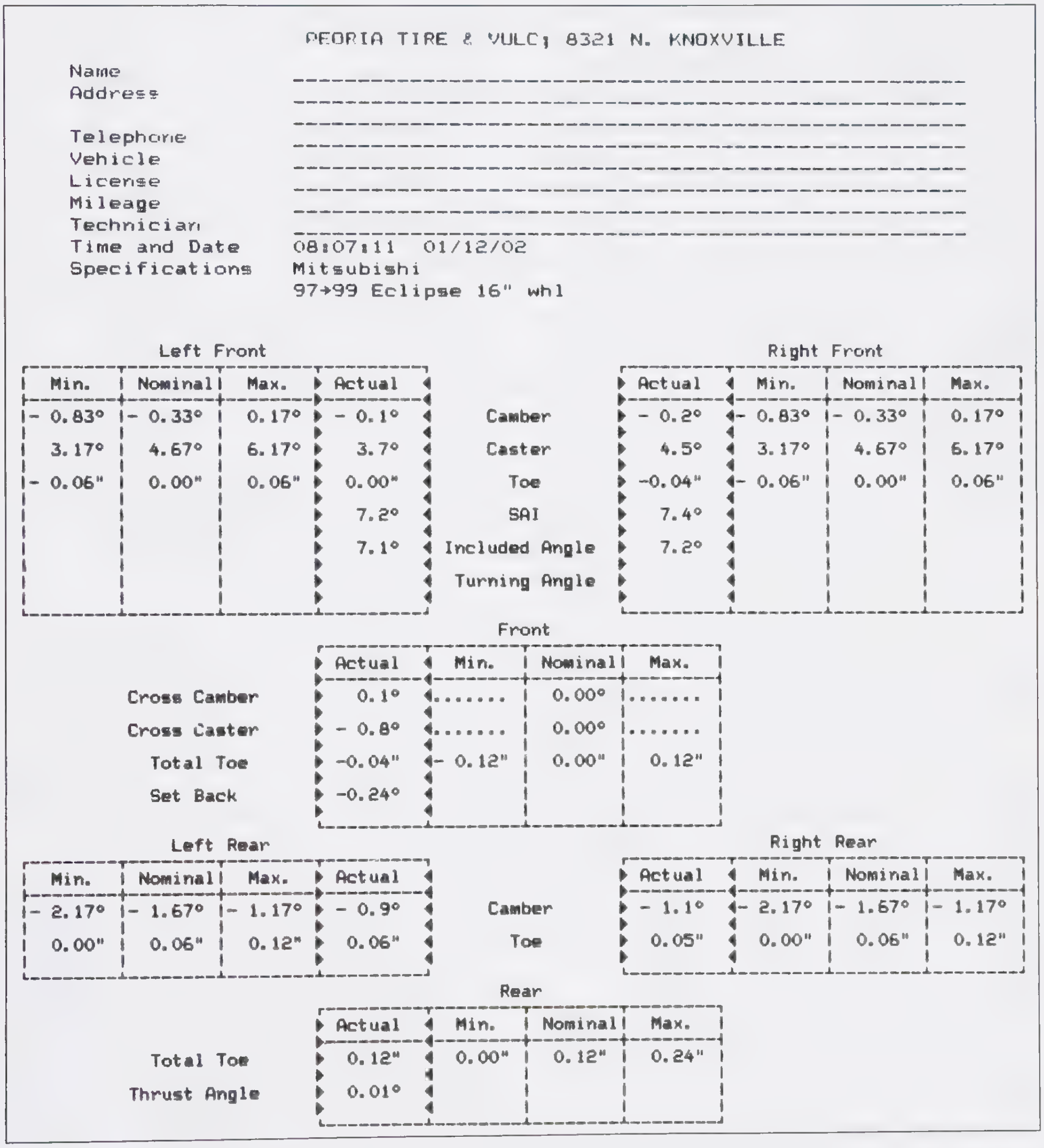
Figure 18-51. *A special socket is needed to remove this locking lug nut.*

involves checking to see that the rear wheels follow directly behind the front wheels, as well as checking front wheel alignment. Front-wheel-drive vehicles with no adjustments in the rear wheels should be given a thrust-angle alignment.

Front-wheel-drive vehicles with adjustable rear wheels require a four-wheel alignment. A ***four-wheel alignment*** checks and sets all four wheels to specifications. Sample specifications for a four-wheel alignment are shown in **Figure 18-52**. These specifications are given in degrees. Note that the specifications list a range of acceptable values. Ideally, the alignment values should be in the middle of the range. For example, if the range for the toe is given as -0.05 to 0.15, the value of 0.05, halfway between -0.05 and 0.15, is ideal.

A vehicle involved in a collision that affects any wheel should be aligned as part of the repair process. Even if the wheels are not hit, the vehicle should be aligned if the frame or unibody is damaged and repaired or replaced. If any suspension part, such as the center link, tie rod end, rack-and-pinion assembly, or ball joint, is worn and replaced, the vehicle should be aligned. Alignments are often performed at the end of the repair process, just before the customer picks up the vehicle.

Unfortunately, problems such as bent steering or suspension parts or frame misalignment are often discovered during the alignment. This causes a delay in the repair, ordering and replacing parts, or returning the vehicle to the frame machine for additional pulling. A thorough inspection of the damage before repairs



```
                    PEORIA TIRE & VULC; 8321 N. KNOXVILLE
    Name              ---------------------------------------------
    Address           ---------------------------------------------
                      ---------------------------------------------
    Telephone         ---------------------------------------------
    Vehicle           ---------------------------------------------
    License           ---------------------------------------------
    Mileage           ---------------------------------------------
    Technician        ---------------------------------------------
    Time and Date     08:07:11  01/12/02
    Specifications    Mitsubishi
                      97→99 Eclipse 16" whl

              Left Front                                          Right Front
 | Min.   | Nominal| Max.   ▶ Actual ◀                    ▶ Actual ◀ Min.   | Nominal| Max.   |
 |- 0.83° |- 0.33° | 0.17°  ▶ - 0.1° ◀  Camber            ▶ - 0.2° ◀- 0.83° |- 0.33° | 0.17°  |
 | 3.17°  | 4.67°  | 6.17°  ▶   3.7° ◀  Caster            ▶   4.5° ◀ 3.17°  | 4.67°  | 6.17°  |
 |- 0.06" | 0.00"  | 0.06"  ▶  0.00" ◀  Toe               ▶ -0.04" ◀- 0.06" | 0.00"  | 0.06"  |
 |        |        |        ▶   7.2° ◀  SAI               ▶   7.4° ◀        |        |        |
 |        |        |        ▶   7.1° ◀  Included Angle    ▶   7.2° ◀        |        |        |
 |        |        |        ▶        ◀  Turning Angle     ▶        ◀        |        |        |

                                        Front
                           ▶ Actual ◀ Min.    | Nominal| Max.    |
          Cross Camber     ▶   0.1° ◀.......  | 0.00°  |.......  |
          Cross Caster     ▶ - 0.8° ◀.......  | 0.00°  |.......  |
          Total Toe        ▶ -0.04" ◀- 0.12"  | 0.00"  | 0.12"   |
          Set Back         ▶ -0.24° ◀         |        |         |

              Left Rear                                           Right Rear
 | Min.   | Nominal| Max.   ▶ Actual ◀                    ▶ Actual ◀ Min.   | Nominal| Max.   |
 |- 2.17° |- 1.67° |- 1.17° ▶ - 0.9° ◀  Camber            ▶ - 1.1° ◀- 2.17° |- 1.67° |- 1.17° |
 | 0.00"  | 0.06"  | 0.12"  ▶  0.06" ◀  Toe               ▶  0.05" ◀ 0.00"  | 0.06"  | 0.12"  |

                                        Rear
                           ▶ Actual ◀ Min.    | Nominal| Max.    |
          Total Toe        ▶  0.12" ◀ 0.00"   | 0.12"  | 0.24"   |
          Thrust Angle     ▶  0.01° ◀         |        |         |
```

Figure 18-52. *Alignment specifications list the specified alignment values. Note that the actual (on the car) alignment values are also shown here.*

are made, and proper measuring during frame repair, should minimize the number of problems uncovered during alignment.

Wheel Alignment Angles

Wheel alignment involves a number of specialized angles, including toe, camber, and caster. Toe is an adjustable dimension on the front wheels of most vehicles and on the rear wheels of some vehicles. ***Toe*** is the tire's orientation in relation to vehicle's centerline. If the tires are pointing straight, there is zero toe. If the tires are pointed slightly inward at the front, **Figure 18-53**, they are toed in (positive toe). If the tires are pointing outward at the front, they are said to be toed out (negative toe). The toe specification is listed in degrees or inches. Adding the left and right toe readings together determines ***total toe***. The toe reading at each wheel should be one half the total toe.

A crude way to check toe is to measure the distance between the front of the tires and the rear of the tires on the same axle. If the distances are equal, toe is zero. If the distance at the front of the tires is smaller than the distance at the rear, the tires are toed in. If the distance at the front is greater than the distance at the rear, the tires are toed out. Toe specification is listed in degrees. Rear wheels may have adjustable rear toe. A rear wheel with greater-than-specified toe-in will cause the vehicle to pull to the same side as that wheel.

Camber is the inward or outward tilt of the tire when viewed from the front of the vehicle. The camber angle is measured from a vertical reference line. See **Figure 18-54**. If the tire is tilted out at the top, the wheel assembly has positive camber. If the tire is tilted in at the top, the wheel assembly has negative camber. If the tire is perfectly vertical, the wheel assembly has zero camber. Improper camber will cause the vehicle to pull to one side and lead to excessive tire wear. If one wheel has too much positive camber, the vehicle will pull to that side. Too much negative camber on one wheel will cause the vehicle to pull to the opposite side.

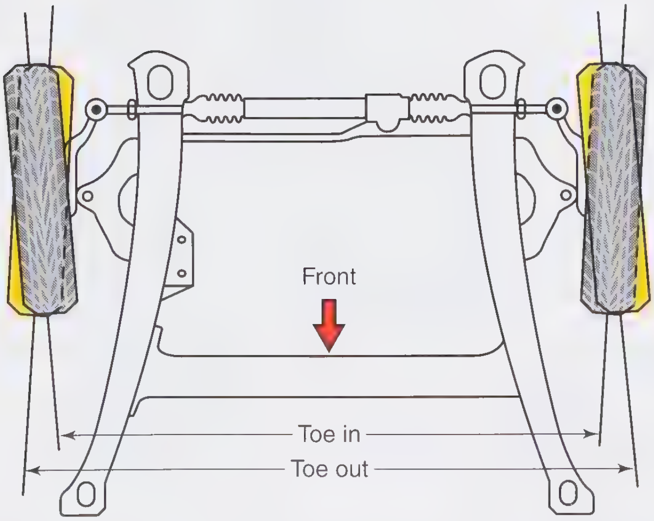


Figure 18-53. *Toe-in means the wheels are pointed toward the centerline. Toe-out means the wheels are pointed away from the centerline.*

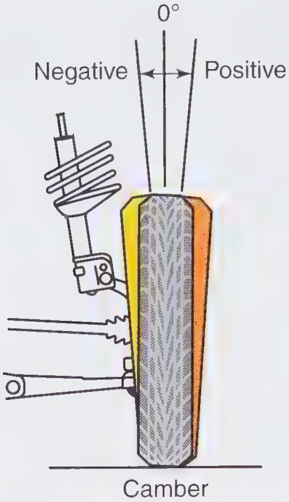


Figure 18-54. *Negative camber means the top of the wheel is pointed toward the center of the vehicle. Positive camber means the top of wheel is pointed away from the center of the vehicle.*

Cross camber is the comparison of the camber on the left and right sides of the vehicle. Both sides should be positive or negative. The cross camber values should be within 0.25° of each other. Camber is adjustable on many vehicles.

The steering axis inclination and included angle can be measured on both short/long-arm suspensions and MacPherson strut suspensions. The ***steering axis inclination*** (SAI) is the angle between an imaginary line through the upper and lower ball joints, or the lower ball joint and strut mount, and a true vertical line. The ***included angle*** is the sum of the SAI and the camber angle. See **Figure 18-55**.

The ***caster angle*** is the difference between the steering axis and true vertical. Caster is viewed from the side of the vehicle as shown in **Figure 18-56**. The steering axis is an imaginary line formed between the upper and lower ball joints or the lower ball joint and the strut mount. If the lower ball joint is ahead of the upper ball joint or strut mount, the vehicle has positive caster. Negative caster means the upper ball joint or strut mount is ahead of the lower ball joint. Improper caster does not result in tire wear. However, improper caster will cause the vehicle to pull. If the caster is different for each front wheel, the vehicle will pull

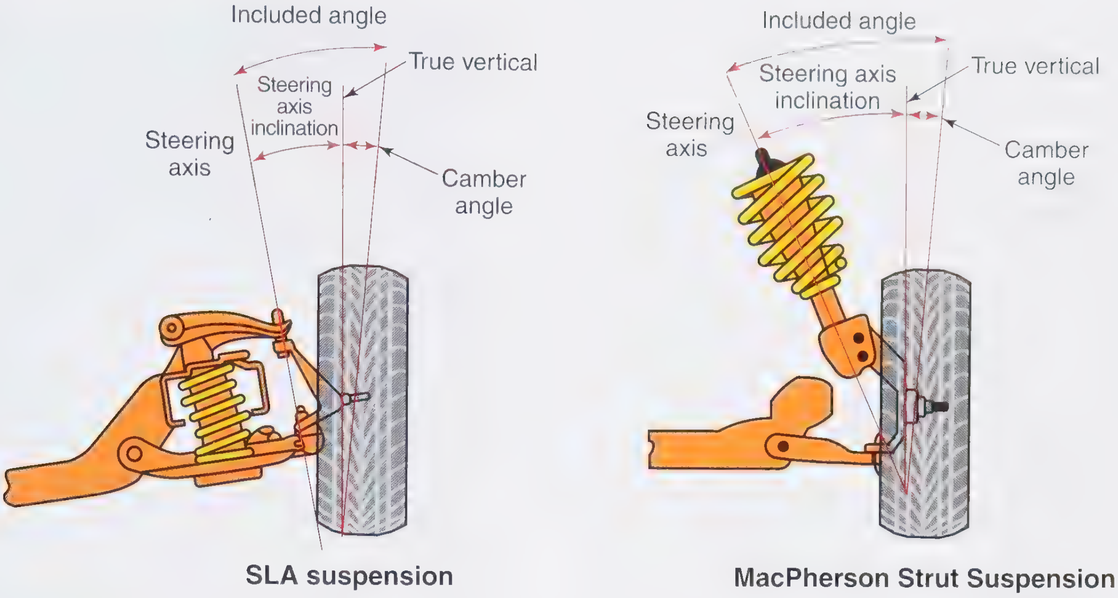

Included angle
True vertical
Steering axis inclination
Steering axis
Camber angle
SLA suspension
Included angle
Steering axis inclination
True vertical
Steering axis
Camber angle
MacPherson Strut Suspension

Figure 18-55. *Steering axis inclination is the angle between the steering axis and true vertical. The included angle is the SAI plus the camber angle. The diagrams show vehicles with positive camber.*

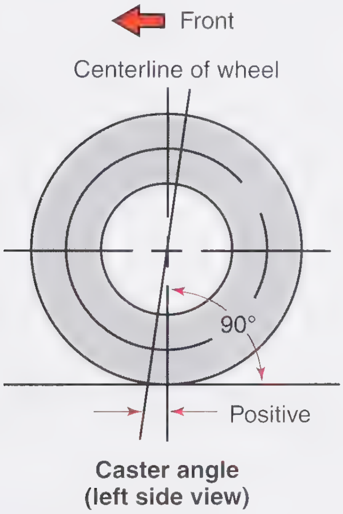

Front
Centerline of wheel
90°
Positive
Caster angle
(left side view)

Figure 18-56. *In positive caster, the lower ball joint is ahead of the upper ball joint or strut mount.*

toward the side with the least-positive caster. This means that if both wheels have negative caster, the vehicle will pull toward the wheel that has the greatest amount of negative caster. ***Cross caster*** is the sum of the left and right caster values. Cross caster should not be more than 0.5°.

Most wheels are centered in the wheel openings. A front impact on a wheel may drive the wheel back as the suspension is damaged. If the wheel on the damaged side of the vehicle is positioned farther back than the wheel on the undamaged side, the wheel on the damaged side is said to have setback. ***Setback*** actually means that the center of the wheel on one side of the vehicle is not directly across from the center of the wheel on the other side of the vehicle. Due to manufacturing tolerances, a small amount of setback is normal. Excessive setback is most often the result of a front impact. However, a rear impact that hits a front wheel can drive the impacted wheel forward. A change in setback causes a caster change on the impact side. A caster difference of 1° or more indicates excessive setback.

Alignment Procedures

NOTE

The procedure for performing a four-wheel alignment is outlined in this section. This procedure is for a repaired, collision-damaged vehicle. During a thrust angle or front end alignment, the same procedures are followed but the rear wheels are not adjusted.

Begin alignment by carefully driving the vehicle onto the alignment rack. Make sure the tires are centered properly on the turn plates. With the vehicle on the rack, check the tire pressure specifications. Inflate or deflate the tires as needed. Then check the vehicle's ride height and compare it to specifications. Finally, make sure the vehicle's curb weight is correct.

Checking for Steering and Suspension Component Wear

To check for steering linkage wear, jack up the vehicle on the alignment rack and support it on jack stands so the suspension is not supporting the weight of the vehicle. The front wheels should be pointing straight ahead. Play may be found in good components if the wheels are turned during inspection.

Grasp the front tire as shown in **Figure 18-57**. Push and pull on the front and rear of the tire. Looseness or play indicates worn steering system parts. If looseness is felt on a vehicle with a rack-and-pinion steering system, check for play in the outer tie rod. Grab the outer tie rod where it attaches to the steering knuckle and push it up and down. Also pull the outer tie rod toward the center of the vehicle and then push it away from the center of the vehicle. If the outer tie rod feels loose, it is worn and must be replaced before the vehicle can be aligned. If there is looseness at the tire and there is no play in the outer tie rod, the portion of the inner tie rod that bolts to the rack is worn.

If looseness is felt on a parallelogram steering system, check the tie rod ends, tie rods, center link, idler arm, and pitman arm individually. Wear will be indicated by looseness or wobble. Replace all worn components before attempting to align the vehicle.

Figure 18-58 shows how to check for worn ball joints. Jack up the vehicle so the weight is off the front wheels. Use a lift or jack stands to safely support the vehicle. If the coil spring is mounted between the lower control arm and the frame, jack up and support the vehicle by the control arm to unload the ball joint for a proper test.

Grab the top and bottom of the tire. Try to move both hands in and out in opposite directions. Look at the suspected ball joint while the tire is moved. Movement of more than 1/4" (6.25 mm) indicates a worn ball joint.

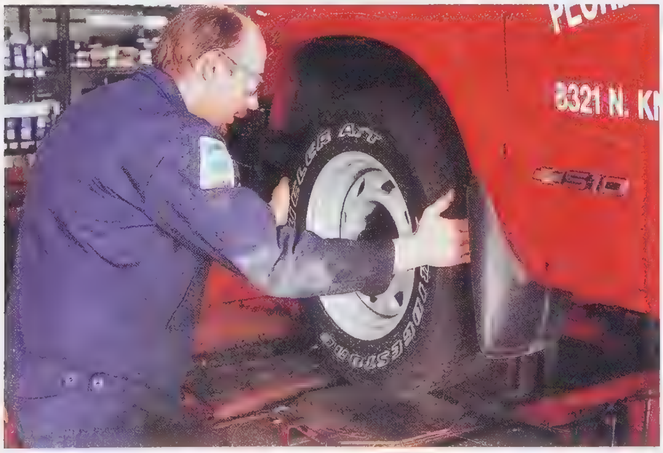


Figure 18-57. *Check for looseness in the steering linkage by grabbing the wheel at the front and rear, and wiggling the wheel.*

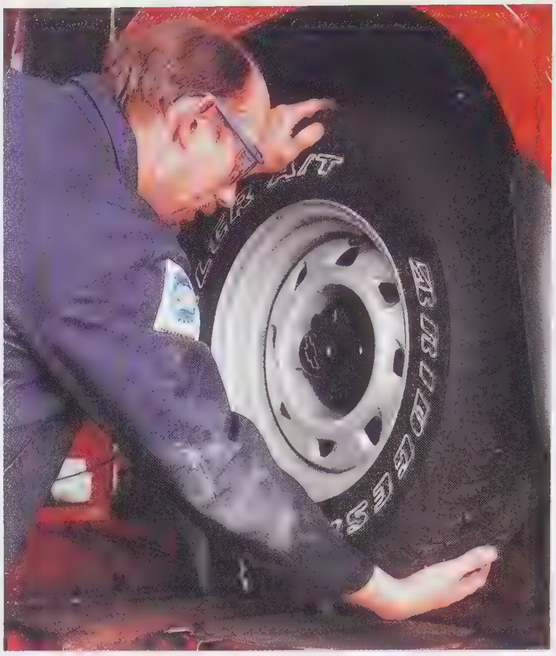


Figure 18-58. *Check for worn ball joints by grabbing the wheel at the top and bottom, and wiggling the wheel.*

Installing Control Heads

After checking for worn parts, lower the vehicle back down onto the alignment rack and install a control head on each wheel that will be aligned. The control head communicates the position of the wheel to a computer. The control head arms fit into the lip of the wheel. See **Figure 18-59**. A safety line on the control head is threaded into the wheel's valve stem. The safety

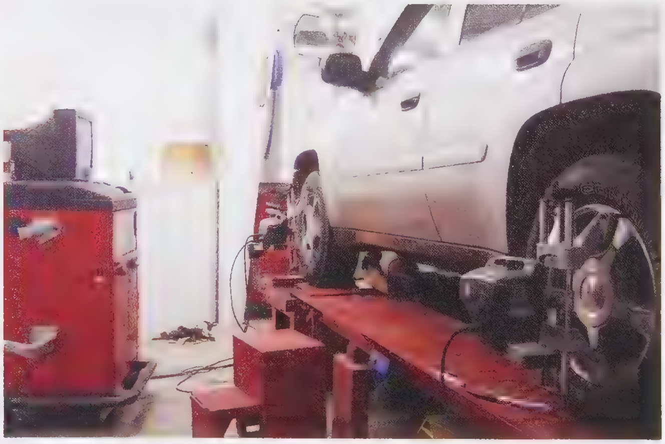


Figure 18-59. *The control heads are mounted to the lips of the wheels.*

line keeps the control head from falling to the floor if the arms slip out of the lip. Once the control head is mounted on the wheel, it must be calibrated following the alignment equipment manufacturer's instructions. This usually involves turning a knob to level and center the control head.

Measuring Actual Alignment Values

After the control heads are installed, the computer monitor will display various alignment measurements in a four-wheel alignment, as well as the range of tolerances for each measurement. See **Figure 18-60**. For the front wheels, camber, caster, toe, SAI, included angle, turning radius, cross camber, cross caster, total toe, and setback are displayed. For the rear wheels, camber, toe, total toe, and thrust angle are shown. Most monitors will display measurements that are within specification in green letters and numbers. Measurements that are out of specification will be displayed in red letters and numbers. Some systems will display where and how to make adjustments by displaying an illustration of the underside of the vehicle with the parts identified. The monitor will also display the steps necessary to make the alignment.

Front camber is measured with the front wheels pointing straight ahead on the turn plates. Camber is a direct reading. The orientation of the control head mounted on each wheel is sent to the computer. The computer calculates the camber (degrees of tilt of the top of the wheel). The monitor displays the actual camber reading. Toe is also a direct reading. The toe reading for each wheel is displayed, as well as total toe for front and rear wheels.

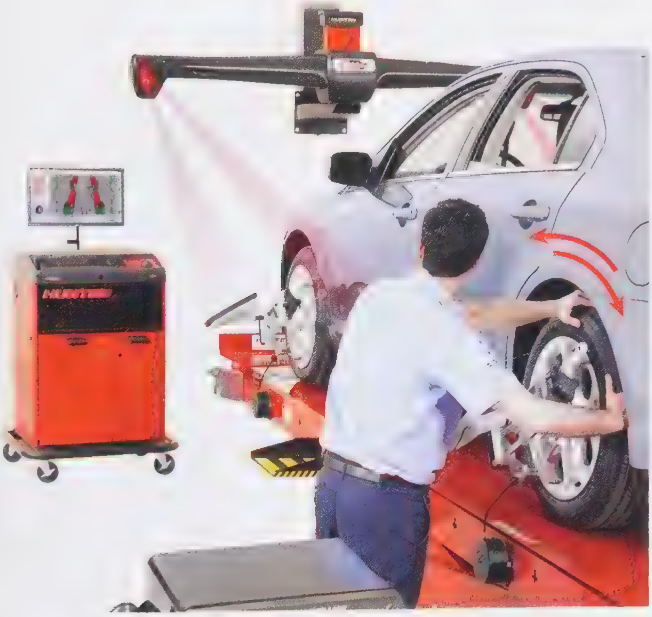


Figure 18-60. *The control heads are mounted on both front and rear wheels. The technician can watch the computer monitor to read the alignment values. (Hunter)*

Caster is not measured directly. Instead, a caster sweep must be performed to measure caster. To make a caster sweep, start with the front wheels pointed straight ahead and push the front of the left front wheel as far as it will go toward the center of the vehicle, as if the vehicle were making a right turn. Next, pull the wheel all the way past the straight ahead position to the maximum left turn position. The control heads will send the computer information about the position of each wheel at the two extremes of the turn. The computer will calculate caster from these wheel position measurements.

NOTE

The wheels can also be turned using the steering wheel during the caster sweep.

To measure SAI, again do a caster sweep but this time jack up the front wheels before making the test. The front wheels will droop with the front end raised. This increases the length of the suspension, stretching the SAI to its maximum angle and allowing SAI to be more accurately measured. The included angle will also be calculated at this time.

If the SAI is incorrect, either a unibody component or suspension component is bent. If unibody damage is suspected, take measurements of the strut nuts and lower ball joint locations. The undamaged side of the vehicle can be used for comparison. A shifted engine cradle will give a high reading on one side and a low reading, by the same amount, on the other side. If the included angle is out of specification or if the comparison of the side-to-side included angle is more than 0.5° off, suspension damage is probable. Once the SAI and included angles are known to be correct, the rest of the alignment angles can be set.

Turn plates can also be used to measure turning radius. Some alignment machines use the control heads instead of the turn plates to measure turning radius. The toe setting must be within specification to test turning radius. If turn plates will be used to check turning radius, turn one wheel to the 20° position and look at the amount the opposite wheel has turned. Then do the same test with the other front wheel. Check values obtained against specifications. The turning radius of each wheel must be within 1.5° of the specifications. A turning radius that is out of specification usually indicates a bent steering arm. If the turning radius check finds that the steering arm is bent, the steering knuckle must be replaced before the alignment can proceed.

Figure 18-61 shows how to interpret alignment measurements to determine which parts are damaged or misaligned.

Adjusting Alignment Angles

After all alignment angles are measured, alignment adjustments should be made in the following order:

1. Set the rear camber.
2. Set the rear toe.
3. Set the front camber and caster on one side of the vehicle.
4. Set the front camber and caster on the other side of the vehicle.
5. Set the front toe.

The general procedures for adjusting camber, caster, and toe are outlined in the following sections.

Adjusting Camber or Caster

Camber or caster may be adjustable on some MacPherson strut vehicles. Moving the top of the MacPherson strut changes the steering geometry. Moving the top of the strut forward or rearward changes the caster. Moving the top of the strut toward or away from the center of the vehicle changes the camber. See **Figure 18-62**. In this example, spot welds are drilled

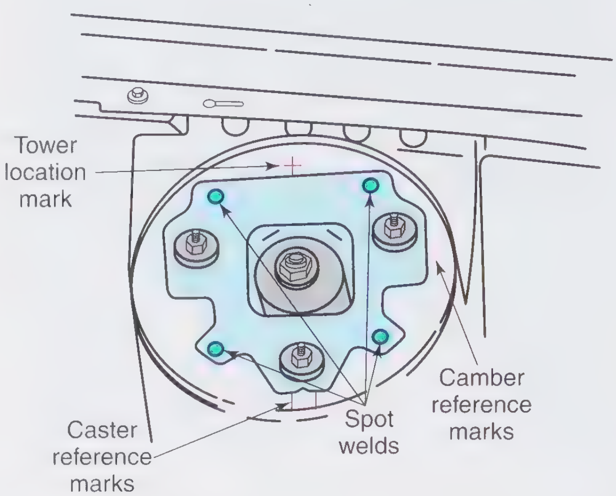


Figure 18-62. *Drilling out the spot welds will allow the top of this strut to be repositioned.*

MacPherson Strut Suspension			
SAI	**Included angle**	**Camber**	**Problem**
OK	OK	OK	no problem
OK	below specs	below specs	bent spindle &/or strut
OK	above specs	above specs	bent spindle &/or strut
Below specs	OK	above specs	shock tower out at top/bent lower control arm
Below specs	above specs	above specs	shock tower out at top/bent lower control arm
Below specs	below specs	below specs	strut tower out at top or bent lower control arm, knuckle or strut
Above specs	OK	below specs	shock tower in at top
Above specs	above specs	above specs	shock tower in at top, bent spindle or strut
Short Arm/Long Arm and Modified Strut Suspension			
SAI	**Included angle**	**Camber**	**Problem**
OK	OK	OK	no problem
OK	below specs	below specs	bent knuckle or spindle
Below specs	OK	above specs	bent lower control arm
Below specs	above specs	above specs	bent lower control arm, knuckle or spindle
Above specs	OK	below specs	bent upper control arm

Figure 18-61. *This chart summarizes the relationship between SAI, camber, and included angle measurements and damage or misalignment.*

out and the nuts are loosened. The strut is moved to the desired location and the nuts are tightened. On other vehicles, the nuts are loosened and the top of the strut is moved. Another adjustment method is shown in **Figure 18-63**. The lower bolt hole in the strut is filed to create a slot. This allows the strut to be moved in or out at the bottom, changing camber.

On short/long arm suspension, the camber and caster can be adjusted with shims, slotted holes, or eccentric cams. When using shims, shims are taken out or added to change the orientation of the upper control arm. Any movement of the upper control arm may affect both the caster and camber. The control arm may have slotted holes. The bolts are loosened and the control arm is moved to the proper location. Eccentric cams work in the same way. A locknut is loosened and the cam is turned to give the proper reading for camber and caster. An eccentric cam adjustment is shown in **Figure 18-64**. On twin I-beam vehicles, an eccentric bushing is installed in place of the upper ball joint bushing. The orientation of the bushing determines the degree of camber or caster change.

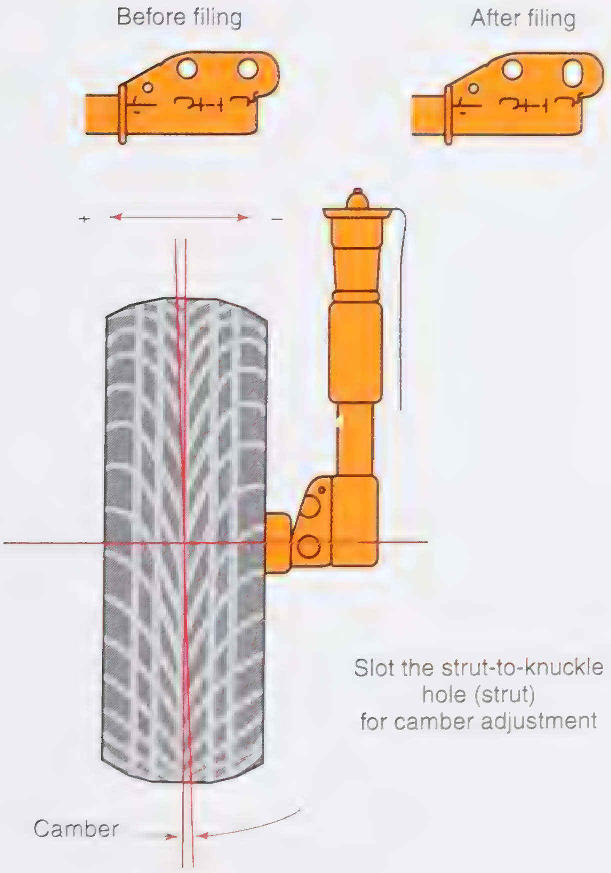

Before filing
After filing
+
–
Slot the strut-to-knuckle hole (strut) for camber adjustment
Camber

Figure 18-63. *Slotting (enlarging with a file) the mounting hole in the strut will change the camber setting.*

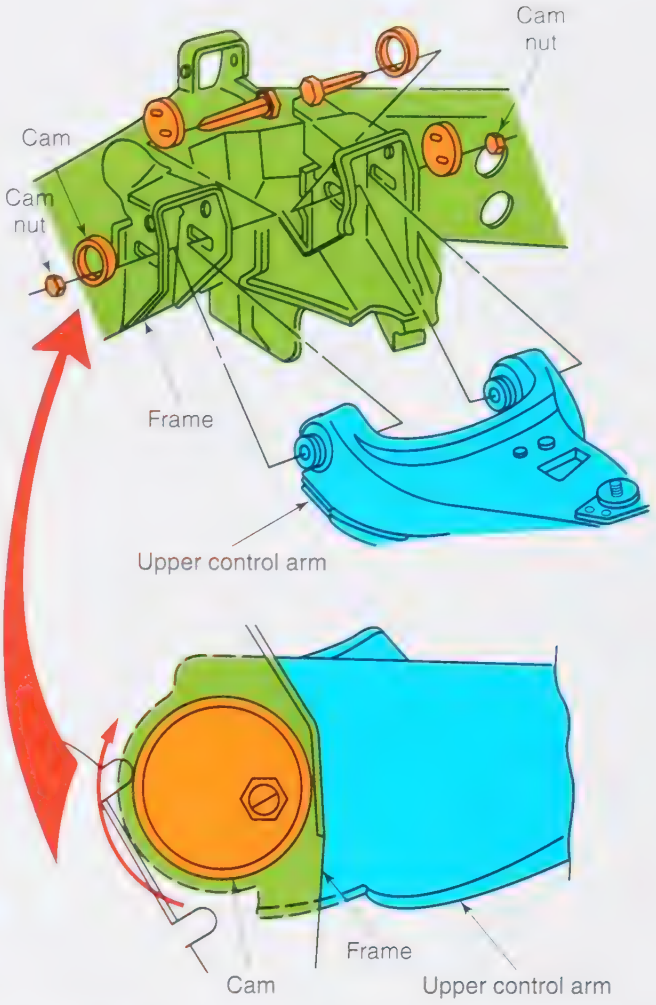


Figure 18-64. *Turning the eccentric cams changes the camber or caster on this full-frame vehicle.*

Adjusting Toe

Front toe can be adjusted on a parallelogram steering system as shown in **Figure 18-65**. Loosen the adjusting sleeve clamp bolts and turn the adjusting sleeve. Turning the adjusting sleeve either moves the front of the wheel toward the center of the vehicle or away from the center of the vehicle by changing the total length of the tie rod.

WARNING

At least 1" of threads must be inside the sleeve; any less is dangerous.

The monitor will display the toe readings as the adjusting sleeve is turned. Some systems will also display a photo of how and which direction to turn the adjusting sleeve so there is no doubt about how

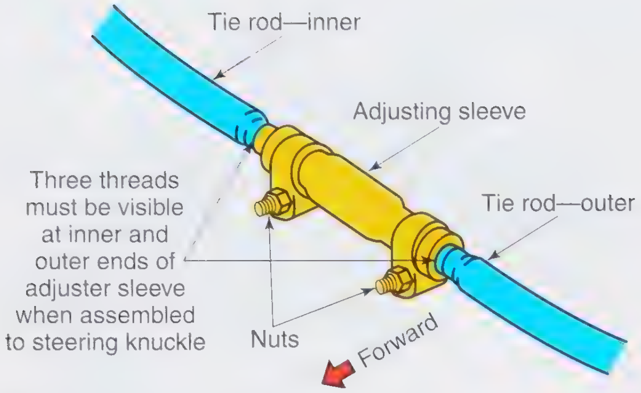

Tie rod—inner
Adjusting sleeve
Three threads must be visible at inner and outer ends of adjuster sleeve when assembled to steering knuckle
Tie rod—outer
Nuts
Forward

Figure 18-65. *To change the toe, loosen the nuts and turn the adjusting sleeve. When the toe reading is correct, tighten the nuts to the specified torque value.*

to make the adjustments. Turn the adjusting sleeve until the toe is correct. Set the toe on one side and then the other. When setting toe, the total length of the left and right tie rods should be equal. Make toe adjustments with equal total length in mind. The total length of the tie rod is the length of the inner tie rod, adjusting sleeve and tie rod end added together. Equalizing the length of tie rods is called centering the steering wheel. If one tie rod is longer or shorter than the other, the steering wheel will be partially turned and not centered when the vehicle is driven straight. The steering wheel is centered in a rack-and-pinion steering system in the same way, equalizing the length of the tie rods.

On a rack-and-pinion system, the tie rod is moved in and out as shown in **Figure 18-66**. Loosen the locknut and turn the tie rod.

Rear toe may be adjustable. On some vehicles, rear toe is adjusted by lengthening or shortening a suspension link. On other vehicles, shims are placed between the rear axle housing and the hub to adjust rear toe.

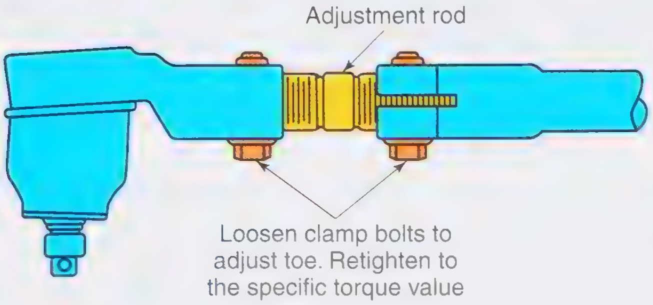

Adjustment rod
Loosen clamp bolts to adjust toe. Retighten to the specific torque value

Figure 18-66. *Loosen the clamp bolts and use a wrench to turn the adjustment rod to change the length of the tie rod.*

Adjusting an Engine Cradle

An engine cradle can be pushed out of alignment in a collision. The cradle does not have to be moved very far to bring it back into alignment. To adjust the cradle, raise the vehicle on a lift and support the cradle with jack stands. Loosen the cradle mounting bolts, but do not remove them. Insert a long pry bar between the cradle and the lower unirail. Pull on the pry bar to reposition the cradle. Usually, the original position of the cradle will be indicated by circles in the unirail's paint. Finally, tighten the cradle's mounting bolts to the proper torque. The computer monitor may suggest moving the engine cradle to correct the alignment values. Moving the engine cradle to one side will change the SAI, camber, and included angle on both sides of the vehicle.

Summary

- There are two basic types of steering systems: rack-and-pinion steering systems and parallelogram steering systems.
- The steering gear changes the rotating motion of the steering shaft to a back-and-forth movement of the steering linkage.
- The steering linkage consists of the components that transfer the motion of the steering gear to the vehicle's wheels.
- The steering knuckle is the connection between the steering and suspension systems.
- The suspension system isolates the vehicle's body from vibrations caused by the up-and-down movement of the wheels. The suspension system also limits the bouncing of the wheels as they travel over rough surfaces, keeping the tires in contact with the road surface.
- Springs are the compressible link between a vehicle's suspension and its body or frame.
- The shock absorbers control spring oscillations.
- A MacPherson strut assembly is a self-contained unit that consists of a shock absorber and a coil spring.
- Control arms are pivoting suspension components that help maintain alignment of the wheel or axle assembly while permitting needed movement.
- Ball joints are ball-and-socket joints that allow suspension components to move up and down, and from side to side.
- Bushings allow suspension components to move without transmitting vibration and noise to the vehicle's frame or body.
- The hub provides a mounting place for the wheel assembly.

- Wheel bearings allow the hub and wheel assembly to rotate easily.
- Front-wheel-drive vehicles should be checked for torque steer.
- Ride height is the distance between a specified point on the vehicle and the shop floor.
- Curb weight is the weight of the vehicle without passengers or cargo, but with a full tank of gas, the engine full of oil, and the cooling system full of coolant.
- Bump steer means that the wheels will steer independently of the steering wheel as the suspension travels up or down over bumps in the road.
- Wheelbase is the distance between the center of the front wheel and the center of the rear wheel.
- Tracking is the ability of the vehicle's rear wheels to track directly behind its front wheels.
- Parts that are subject to wear should be replaced in front or rear pairs.
- An impact on a wheel may move the wheel and bend the strut. A bent strut must be replaced.
- A wheel that is not correctly positioned in the wheel opening may be an indication of a bent lower control arm.
- Never attempt to straighten a damaged hub, spindle, or steering knuckle. These components are not repairable.
- Wheel alignment involves checking the suspension parts for damage or wear, measuring alignment angles, and setting all adjustable angles to specifications.
- Toe is the tire's orientation in relation to vehicle's centerline. If the tires are pointing straight, there is zero toe.
- Camber is the inward or outward tilt of the tire when viewed from the front of the vehicle. The camber angle is measured from a vertical reference line.
- The steering axis inclination (SAI) is the angle between an imaginary line through the upper and lower ball joints, or the lower ball joint and strut mount, and a true vertical line.
- The caster angle is the difference between the steering axis and true vertical. Caster is viewed from the side of the vehicle
- Setback means that the center of the wheel on one side of the vehicle is not directly across from the center of the wheel on the other side of the vehicle.
- After checking for worn parts, control heads are installed on each wheel that will be aligned. The control head communicates the position of the wheels to an alignment computer.
- After the control heads are installed, the computer monitor will display various alignment measurements, as well as the range of tolerances for each measurement.
- After all alignment angles are measured, alignment adjustments should be made in the following order: rear camber, rear toe, front camber and caster on one side of the vehicle, front camber and caster on the other side of the vehicle, and finally front toe.

Review Questions

Please do not write in this textbook. Place your answers on a separate sheet of paper.

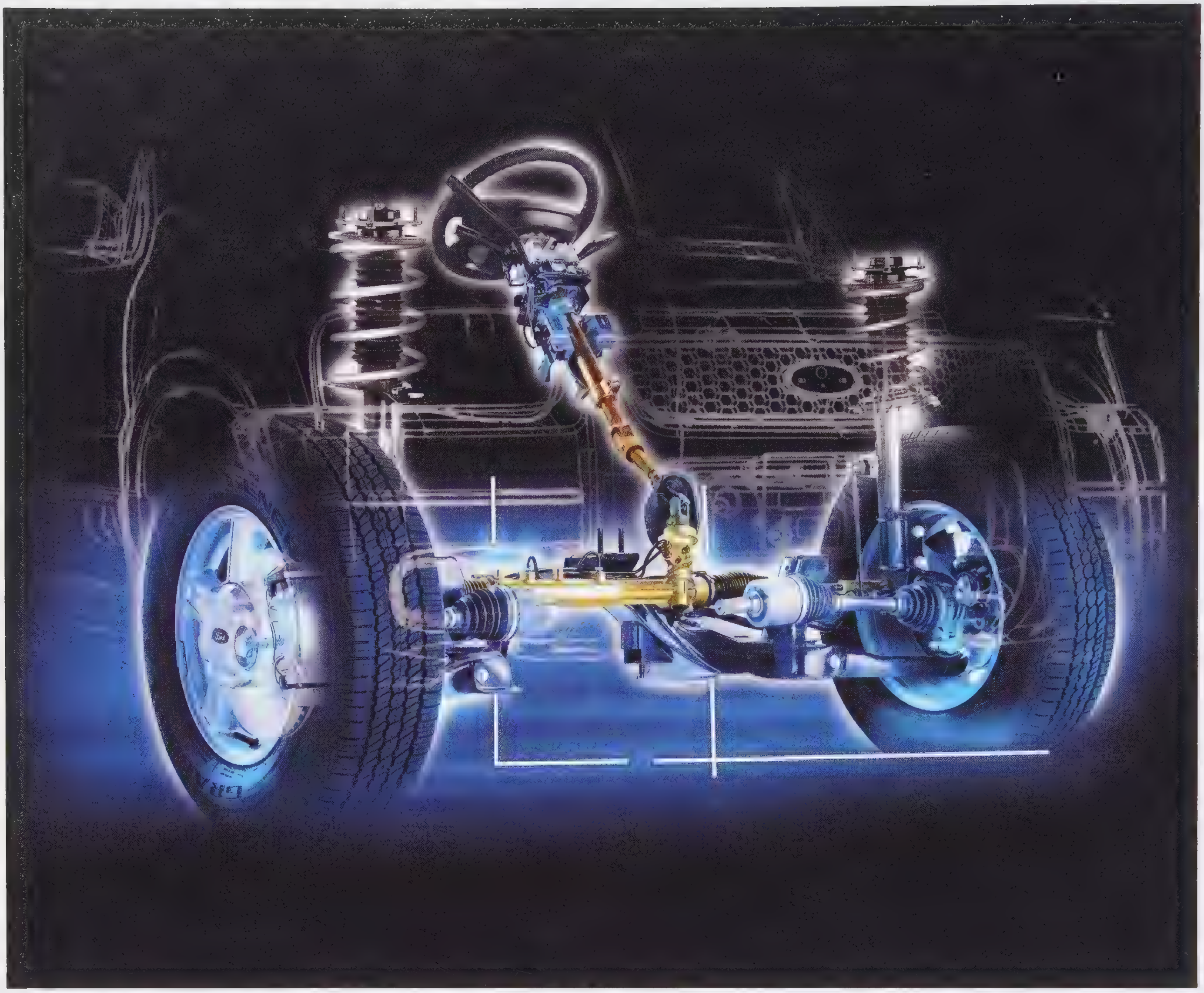
1. The bottom portion of the steering column is designed to ______ during a collision.
2. The ______ is the connection between the steering and suspension systems.
3. In a rack-and-pinion steering system, the pitman arm converts the rotation of the pinion gear to a back-and-forth motion. True or False?
4. In a parallelogram steering system, the ______ provide connections between the ends of the center link and the steering arms.
5. Some power steering systems use an electric power steering pump. True or False?
6. What is the purpose of shock absorbers?
7. In a MacPherson strut front suspension, the strut assembly ______ as the front wheels are turned.
8. The ______ provides a mounting place for the wheels and tire assembly.
9. A vehicle's tires are considered part of the suspension system. True or False?
10. The aspect ratio of a tire is the ratio of the tire's section ______ to its section ______.
11. A comparative tire pressure uses pressure sensors strapped to each wheel to monitor pressure. True or False?
12. Define *torque steer.*
13. What should be done before checking ride height?
14. Explain the procedure for checking for bump steer.
15. Tracking is the relationship of a vehicle's front and rear wheels to its ______.
16. Struts and springs should be replaced in pairs. True or False?
17. Name three methods used to remove rusted fasteners.
18. Why is it important to avoid nicking the point on the spring when replacing a MacPherson strut?
19. A spring ______ is used to remove a coil spring on a short/long arm suspension.
20. What is the weakest part of a stabilizer bar assembly?
21. Toe is always adjustable at the rear wheels. True or False?
22. Define *camber.*

23. Explain the procedure used to check for ball joint wear.
24. List the five alignment adjustments in the order in which they are performed.
25. Moving the top of a strut forward or rearward changes ______.

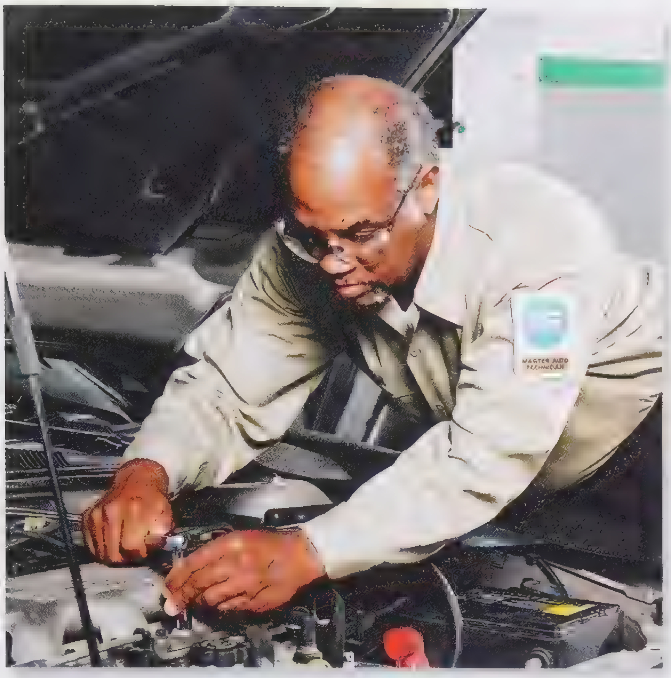
ASE-Type Questions

1. Each of the following is a common steering system part EXCEPT:
   (A) steering column.
   (B) stabilizer bar.
   (C) steering linkage.
   (D) steering knuckle.
2. Technician A says that most power-assisted steering systems use a hydraulic pump to provide steering assist. Technician B says that some power-assisted steering systems use an electric motor to provide steering assist. Who is right?
   (A) A only.
   (B) B only.
   (C) Both A and B.
   (D) Neither A nor B.
3. Technician A says one end of a control arm attaches to the vehicle's frame or body. Technician B says one end of a control arm attaches to the steering knuckle or axle assembly. Who is right?
   (A) A only.
   (B) B only.
   (C) Both A and B.
   (D) Neither A nor B.
4. Technician A says that rack-and-pinion steering systems are found on most late model cars and many light trucks. Technician B says that the parallelogram steering system is found on older cars, as well as some trucks and SUVs. Who is right?
   (A) A only.
   (B) B only.
   (C) Both A and B.
   (D) Neither A nor B.
5. All of the following spring types are commonly used in automotive systems EXCEPT:
   (A) coil springs.
   (B) lever-type springs.
   (C) torsion bars.
   (D) leaf springs.
6. Technician A says that shock absorbers control spring oscillations. Technician B says that without shock absorbers, the vehicles tires would lose contact with the road. Who is right?
   (A) A only.
   (B) B only.
   (C) Both A and B.
   (D) Neither A nor B.
7. All of the following statements about MacPherson strut front suspension systems are true EXCEPT:
   (A) the strut assembly rotates as the front wheels are turned.
   (B) the strut assembly is bolted to the steering knuckle and the strut tower.
   (C) all MacPherson strut front suspension systems contain both upper and lower control arms.
   (D) the MacPherson strut assembly must generally be removed from the vehicle to service its individual components.
8. Technician A says that ride height is the distance between a specified point on the vehicle and the shop floor. Technician B says that curb weight is the weight of the vehicle without passengers, cargo, or fuel. Who is right?
   (A) A only.
   (B) B only.
   (C) Both A and B.
   (D) Neither A nor B.
9. Ball joint positions are compared side to side on a vehicle. The difference is 1/4". Technician A says that this is within accepted limits and that there is no damage. Technician B suspects some type of suspension damage. Who is right?
   (A) A only.
   (B) B only.
   (C) Both A and B.
   (D) Neither A nor B.
10. Technician A says bump steer is present if the wheels steer independently of the steering wheel as the suspension travels up or down over bumps in the road. Technician B says that bump steer is caused by incorrect toe adjustment. Who is right?
   (A) A only.
   (B) B only.
   (C) Both A and B.
   (D) Neither A nor B.
11. Technician A says used parts should not be used as replacements for any parts that are subject to wear. Technician B says that some parts that are subject to wear should be replaced in front or rear pairs. Who is right?
   (A) A only.
   (B) B only.
   (C) Both A and B.
   (D) Neither A nor B.

12. All of the following are accepted methods for freeing rusted fasteners EXCEPT:
    (A) vibration.
    (B) lubrication.
    (C) reverse torque.
    (D) heat.
13. Technician A says that torque-to-yield fasteners can be reused if they are in good shape. Technician B says that many suspension and steering system fasteners must be tightened to a specific torque. Who is right?
    (A) A only.
    (B) B only.
    (C) Both A and B.
    (D) Neither A nor B.
14. Technician A says a spring compressor must be used when removing a spring from a short/long arm suspension. Technician B says a spring compressor is not needed when replacing a MacPherson strut. Who is right?
    (A) A only.
    (B) B only.
    (C) Both A and B.
    (D) Neither A nor B.
15. A wheel alignment calls for a toe setting of 0.05°. The alignment machine says the actual toe is 0.18° (out of range). Technician A wants to adjust the toe to move the front of the tire toward the center of the vehicle. Technician B wants to adjust the toe to move the front of the tire away from the center of the vehicle. Who is right?
    (A) A only.
    (B) B only.
    (C) Both A and B.
    (D) Neither A nor B.
16. The right toe reading is 0.1° and the left toe reading is –0.05°. Technician A says that the total toe is 0.15°. Technician B says that the total toe is 0.05°. Who is right?
    (A) A only.
    (B) B only.
    (C) Both A and B.
    (D) Neither A nor B.
17. Which of the following is negative camber?
    (A) A tire tilted in at the top.
    (B) A tire tilted out at the top.
    (C) A tire pointing straight ahead.
    (D) None of the above.
18. A vehicle pulls to the side with ______.
    (A) the least positive caster
    (B) the most positive caster
    (C) zero caster
    (D) the most negative camber
19. A vehicle has a camber reading of –0.8°(out of range) on the right front wheel and a reading of 0.1°(within range) on the left front wheel. This vehicle will ______.
    (A) pull to the left
    (B) pull to the right
    (C) drive straight
20. The camber on the left front wheel is –0.5°. The camber on the right front wheel is 0.5°. Technician A says that there isn't any problem because they add up to zero. Technician B says that this is a problem because one is positive and the other is negative. Who is right?
    (A) A only.
    (B) B only.
    (C) Both A and B.
    (D) Neither A nor B.
21. A vehicle has a caster reading of 2.8° on the right front wheel and 2.8° on the left front wheel. This will cause the vehicle to ______.
    (A) pull to the left
    (B) pull to the right
    (C) drive straight
22. A vehicle has a caster reading of 2.4° on the right front end and 0.8° on the left front. This will cause the vehicle to ______.
    (A) pull to the left
    (B) pull to the right
    (C) drive straight
23. A four-wheel-drive vehicle has a caster reading of –0.5° on the left front and –3.6° on the right front (out of range). This will cause the vehicle to ______.
    (A) pull to the left
    (B) pull to the right
    (C) drive straight
24. A rear-wheel-drive vehicle has no adjustments on the rear wheels. Technician A wants to do a four-wheel alignment. Technician B wants to do a thrust-angle alignment. Who is right?
    (A) A only.
    (B) B only.
    (C) Both A and B.
    (D) Neither A nor B.
25. Toe is set by ______.
    (A) moving the strut toward the center of the vehicle
    (B) moving the top of the strut to the rear of the vehicle
    (C) turning the adjusting sleeve
    (D) placing shims at the upper control arm



A sophisticated suspension and steering system will not function as designed if the frame is not pulled square and repaired to exact specifications. (Ford)



Chapter 19

Electrical System

Objectives

After studying this chapter, you will be able to:

- Identify electrical system components.
- Understand current flow.
- Diagnose an electrical system problem.
- Remove and replace electrical system components.

Technical Terms

aiming
aiming screws
alternator
atom
battery
bound electrons
circuit breaker
clockspring
conductors
free electrons
fusible link
ground
insulator
interior lights
jumper wire
nonpowered test light
open circuit
parallel circuit
power antenna system
power door lock system
power mirror system
power seat system
power sunroof system
power window system
rear defroster/demister system
relay
replaceable bulb
sealed beam
self-powered test light
series circuit
series-parallel circuit
short circuit
switch
taillights/marker lights
turn signal lamps
wiring harness

Introduction

This chapter discusses the automotive electrical system. Some electrical parts, such as headlights and parking lamps, are commonly damaged in a collision. Electrical problems can be frustrating to fix without a basic understanding of electricity. This chapter gives a background in electricity and covers electrical parts commonly repaired or replaced during the collision repair process.

Basic Electricity

A basic understanding of atomic theory will help you understand how electricity works. All matter is made of atoms. An ***atom*** consists of protons, neutrons, and electrons. Protons have a positive charge, electrons have a negative charge, and neutrons are electrically neutral (have no charge). The number of protons in an atom is equal to the number of electrons. Therefore, for every positive charge in an atom, there is a negative charge. An atom has no overall charge because the positive and negative charges cancel each other out.

The protons and neutrons make up the core, or nucleus, of the atom, while the electrons orbit the nucleus in electron shells. The electron shells are concentric rings around the core. The number and arrangement of the electrons in the outer electron shell determines how the atom will interact with other atoms

In some atoms, the electrons in the outer shell are tightly held and never leave the atom. These are called ***bound electrons***. When the majority of atoms in a material contain bound electrons, the material is called an ***insulato***r, or a nonconductor of electricity.

In most atoms, the electrons in the outer shell are loosely held and can be freed to move from one atom to another. These are called ***free electrons***. Materials made up primarily of atoms with free electrons, such as copper or aluminum, are called ***conductors*** because they conduct electricity.

Electricity is created when electrons move from one conductor atom to an adjacent conductor atom, causing the loosely held outer shell electron or electrons in the second atom to move to the next atom in the line. **Figure 19-1** shows a stack of electrons and a line of copper atoms. An electron from the stack moves to the first copper atom, displacing the electron from that atom. The displaced electron moves to the second copper atom, displacing that electron. That displaced electron moves to the third atom, and so on. The movement of electrons continues through the conductor atoms until the electrons reach a reservoir area of few electrons. In an automotive electrical circuit, the stack of electrons is at the negative battery terminal and the reservoir is the positive battery terminal.

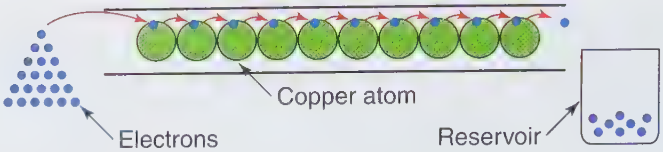


Figure 19-1. *Green circles represent copper atoms. An electron in the stack displaces an electron in the first copper atom. The displaced electron moves to the next copper atom, displacing an electron from that atom. The electron displacement from adjacent copper atoms continues until an electron reaches the reservoir.*

Units of Electricity

To understand electricity, one must understand the role of volts, amps, and ohms. A volt is a measurement electrical force, or voltage. Voltage is created by a difference in number of electrons on each end of a conductor or circuit.

Electrical current is the flow of electrons. It is measured in amperes. One ampere of current is equal to 6,240,000,000,000,000,000 (6.24×10^{18}) electrons flowing past a given point per second. For electrons to flow at this rate, there must be a continuous pathway from the stack of electrons to the reservoir. This continuous pathway is known as a complete circuit. Any disruption of the pathway will not allow electrons to move. If there is a continuous pathway, the circuit is said to have continuity.

Resistance to electron flow is measured in ohms. Resistance limits the flow of electrons. Compare the amount of electrons that can move through a conductor that consists of only a single line of copper atoms to a conductor that has, in cross section, ten copper atoms. See **Figure 19-2**. The ten copper atom conductor offers less resistance than the one copper atom conductor because there are more copper atoms available to move electrons. The one copper atom conductor has more resistance and this limits the flow of electrons. Electrons moving through conductors produce heat. The higher the electron flow, the more heat is produced. Higher temperatures increase resistance.

Ohms Law

The relationship between the units of electricity is expressed by the formula known as Ohm's law. Ohm's law can be used to calculate an unknown circuit value when the other two values are known.

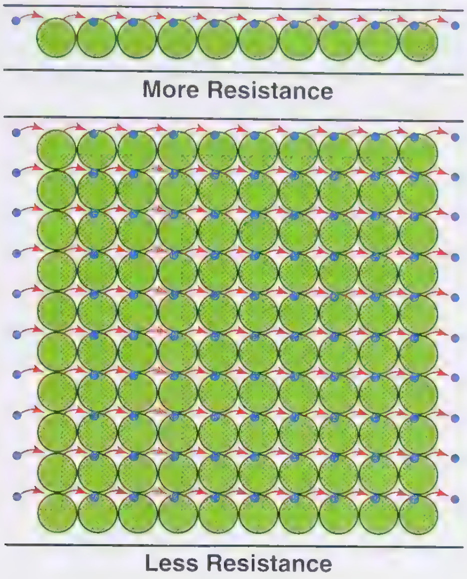


Figure 19-2. *More electrons can move through a conductor with a cross section of 10 copper atoms than a conductor with a cross section of one copper atom.*

Electrical Components and Circuits

All electrical circuits consist of a power source, a load, and electrical conductors. The power source provides the energy to push the electrons through the circuit. In automotive circuits, the battery is the primary power source. The load is a device, such as a motor or a solenoid, that is powered by electricity and does work in the circuit. Conductors provide the pathway for the electrical current between the source and the load. In automotive circuits, copper wire is generally used as the conductor.

An electrical circuit with only one path for electrons to flow through is called a ***series circuit***. A ***parallel circuit*** has more than one path for the electricity to flow through. In this type of circuit, one terminal of each device is connected to a common conductor, which leads to one terminal of the source. A second terminal from each device is connected to another common conductor, which is connected to the other terminal of the battery. ***Series-parallel circuits*** have some electrical devices connected in series and others connected in parallel. See **Figure 19-3**.

Wiring diagrams show the pathway or pathways that electricity can take when flowing from one battery terminal through a circuit to the other battery terminal. In an automobile, the vehicle's body serves as a conductor. It provides a pathway for electron flow known as the ***ground***. In most circuits, the power flows from the battery through the load and to ground. The ground completes the circuit, allowing the electrons to return to the battery. See **Figure 19-4**.

Often, diagnostic instructions require you to connect something to a good ground. A good ground is any bare

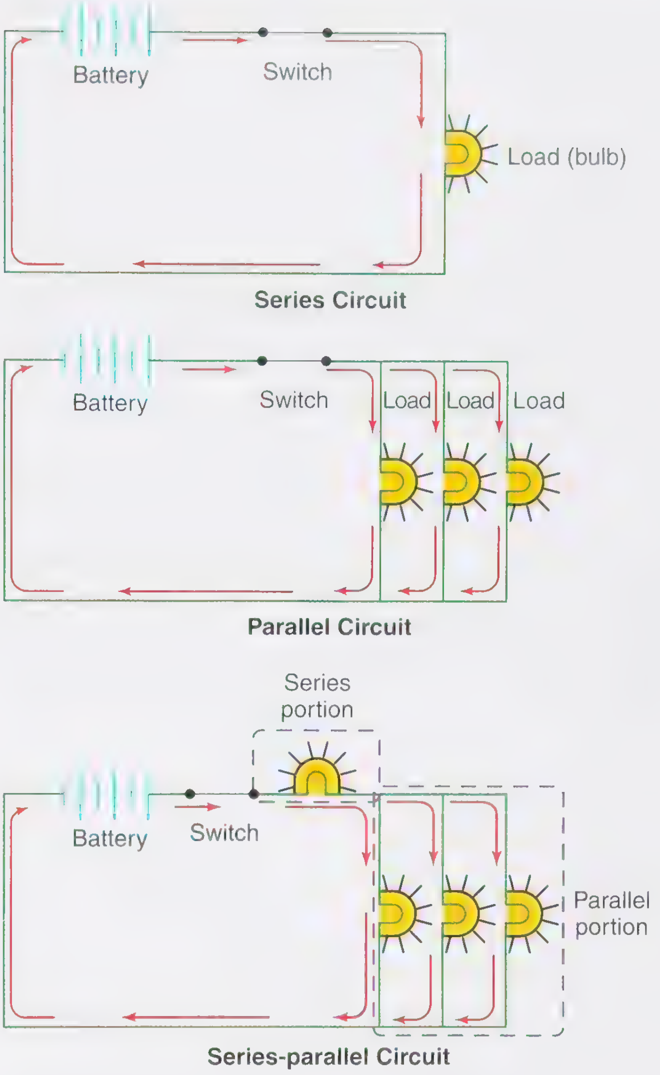


Figure 19-3. *There is only one possible pathway for electron flow in a series circuit. A parallel circuit has multiple pathways for electrons, and a series-parallel circuit has a series portion and a parallel portion.*

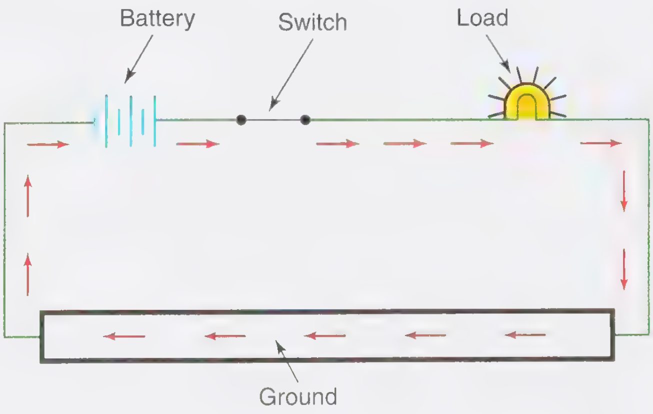


Figure 19-4. *In this example, the vehicle's frame completes the electrical circuit between the load and the battery.*

metal on the vehicle's body or engine block. The paint or undercoat on a vehicle may block the flow of electricity, so painted or coated metal cannot serve as a pathway to ground. Remove the paint or undercoating in the connection area so electricity can flow through bare metal.

Circuit Problems

A broken wire causes an ***open circuit***, or simply, an open. If a wire is broken, electricity will not flow through the circuit. Therefore, the load will not work. See **Figure 19-5**.

A ***short circuit***, or short, occurs when the current takes an unintended pathway. One example of a short circuit is when a bare wire from one circuit touches a bare wire from a different circuit. In this example, electricity from circuit one operates the bulb even when the switch is not turned on. A bare wire touching the body of the vehicle can also create a short circuit. See **Figure 19-6**.

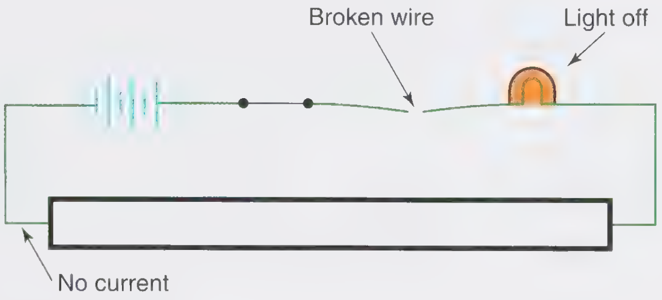


Figure 19-5. *In an open circuit, the load cannot operate. The lamp cannot light because the broken wire will not allow electrons to flow to the light.*

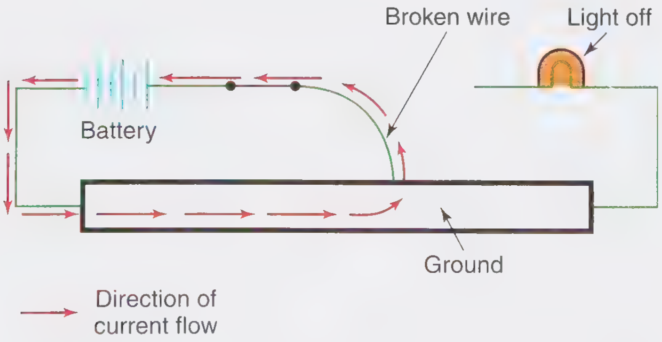


Figure 19-6. *In this circuit, a broken wire touches bare metal, allowing electrons to flow through an incorrect pathway. This is a short circuit. The electrons take a shorter pathway to ground, bypassing the load.*

Many electrical problems are caused by bad grounds. Bad grounds can result from loose or corroded connectors. If the pathway to the battery is broken, electicity will not flow and the load will not operate. Most wires/connectors are made from copper. Copper readily conducts electricity.

Copper that is contaminated by oxidation does not conduct as well as pure copper. Oxidation is also called corrosion. Corrosion increases resistance. The additional resistance will limit current output to the load. A battery is designed to provide a specific voltage to the circuit. The resistance caused by corrosion decreases the voltage to the circuit.

Basic Electrical Parts

The basic electrical parts discussed in this section are specific examples of conductors, controllers, power sources, and loads found in all automotive electrical systems. Together, these electrical parts provide power, provide a pathway for electron flow, regulate the flow of electricity, and convert electrical energy to mechanical work.

Wire

Automotive electrical wire consists of two components: a conductor and an insulator. The conductor (wire) provides the pathway for electrical current, while the insulator prevents electricity from flowing anywhere but through the conductor. The insulator surrounds the conductor. If the insulator is broken, the conductor may touch bare metal. This causes a short circuit because the conductor is grounded. Therefore, electricity may not reach the intended load.

Wires carrying current to loads have color-coded insulators. For example, one wire may have a green insulator with a black stripe. Other wires will have different color schemes. This allows the wires to be easily identified and distinguished from each other. Wires are bundled together in a ***wiring harness***. **Figure 19-7** shows a typical wiring harness.

Wire Terminals and Connectors

Terminals and connectors make a continuous pathway for electrons from a wire to a load or from wire to wire. Terminals and connectors, which fit together like a lock and a key, are plugged together for a tight connection. A terminal is at one end of a wire. A connector joins with the terminal to make a complete circuit. Often, many wires are joined together with multiple terminals or connectors encased in plastic blocks. See **Figure 19-8**.

Figure 19-7. *This is a wiring harness that runs from the body of a vehicle to the door. These wires convey power to the window regulator, door lock, and speaker.*

NOTE

Connectors often have a locking tab to prevent the connectors and terminals from separating. Figure 19-8 shows one type of connection. The tab is moved out of the way to allow the connectors to separate.

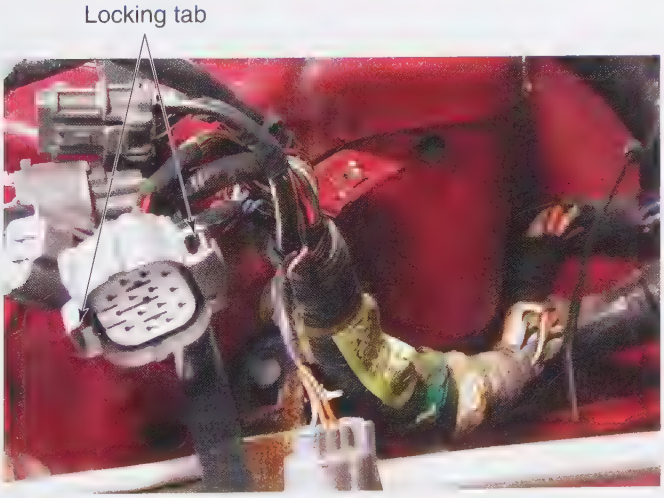

Locking tab

Figure 19-8. *The locking tabs on this connector make a secure connection between wires.*

Switches and Relays

A ***switch*** is used to turn on and turn off the flow of electricity. When a switch is off (open), the circuit is not complete and current cannot flow. When the switch is on (closed), the circuit is complete and current can flow. Some switches, such as power window switches, are wired so they receive power only when the ignition key is turned on. Other switches are powered at all times. An example of a switch that is powered all the time is the headlight switch.

A ***relay*** is a magnetic switch that uses a low-voltage signal from a remote location to control the on-and-off operation of a high-voltage circuit. This allows for a shorter path for the high voltage, minimizing voltage drop.

In a relay, low-voltage current flows through a wire that is coiled around an iron rod, creating an electromagnet. When energized, the electromagnet moves an arm, which closes contacts to complete a high-voltage circuit. **Figure 19-9 A** and **B** show how a relay works.

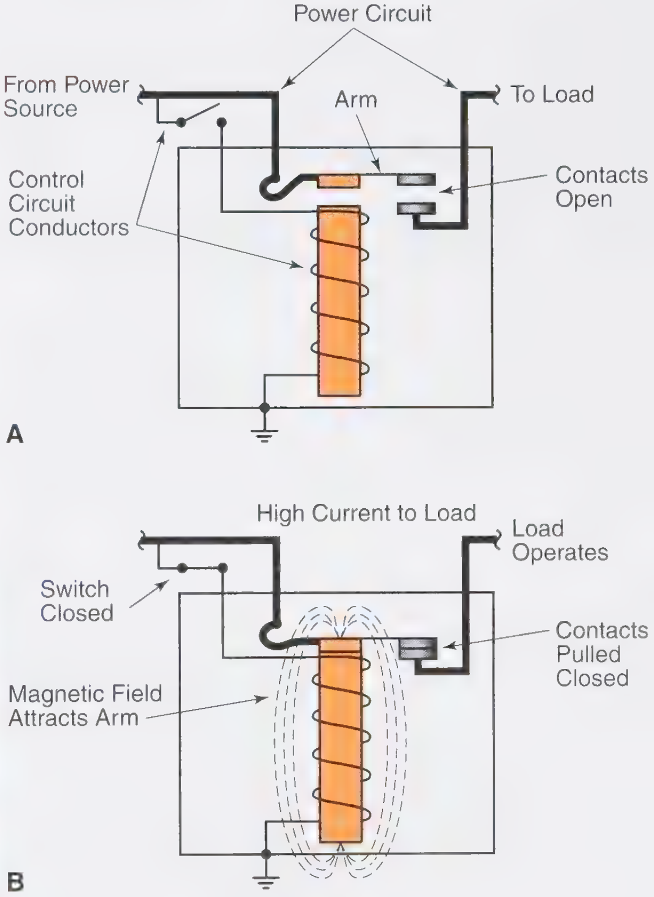

Power Circuit
From Power Source
Arm
To Load
Control Circuit Conductors
Contacts Open
A
High Current to Load
Load Operates
Switch Closed
Contacts Pulled Closed
Magnetic Field Attracts Arm
B

Figure 19-9. *A—A simple relay can be used as a high-current switch. Current flowing through a winding around an iron rod turns the rod into a magnet. B—The magnet attracts the arm to close the contact points. This completes a circuit, allowing current to flow to the motor (load).*

Fuses, Fusible Links, and Circuit Breakers

If the insulation is scraped off a wire and the wire touches bare metal, a short circuit will occur. Electrons will flow from the wire through the bare metal to ground. The pathway may have less resistance than the original circuit. Even if it has the same resistance as the original circuit, unrestricted current can flow because the load is bypassed. The short circuit allows an unrestricted amount of current to pass through the wire. Unrestricted current produces heat, enough heat to melt wires or cause a fire.

Fuses, fusible links, and circuit breakers prevent unrestricted current flow. They stop current flow if it gets too high, preventing damage to other components in the electrical system.

Fuses are rated by the maximum amount of current they allow to pass through them. For example, a 5-amp fuse will allow five amps of current to pass through it. If the current flow is greater than the fuse rating, the heat generated by the current will cause the fuse to "blow." When the fuse blows, its element melts, creating an open circuit and stopping current flow. See **Figure 19-10**. A fuse block holds the fuses for the vehicle's various circuits. Fuse blocks are located in the engine compartment or under the instrument panel. **Figure 19-11** shows a fuse block.

A ***fusible link*** is a wire that is sensitive to excessive current. If excessive current is present, the wire melts, opening the circuit. When this occurs, the insulation around the melted link will look loose and soft. Both fuses and fusible links must be replaced after they blow or melt.

A ***circuit breaker*** also stops excessive current flow, but unlike a fuse or fusible link, it is not permanently damaged by high current flow. The heat generated by excessive current in a circuit causes contacts inside the circuit breaker to separate. This creates an open circuit inside the circuit breaker, stopping current flow and protecting the electrical system from damage. Once the circuit breaker cools down, the contacts inside the breaker join back together, reestablishing the circuit. Some circuit breakers must be reset manually.

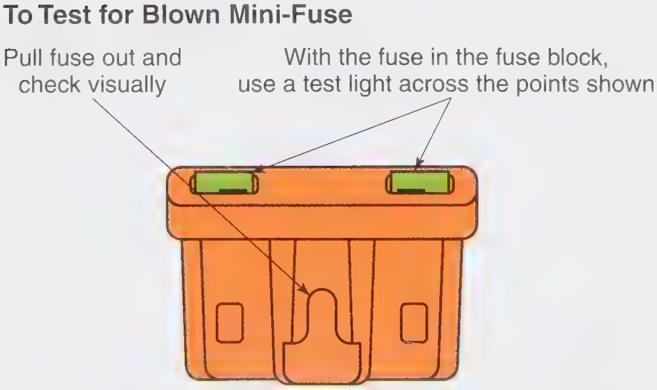

To Test for Blown Mini-Fuse
Pull fuse out and check visually
With the fuse in the fuse block, use a test light across the points shown

Figure 19-10. *Excessive current through the fuse causes the internal circuit of the fuse to melt, stopping current.*

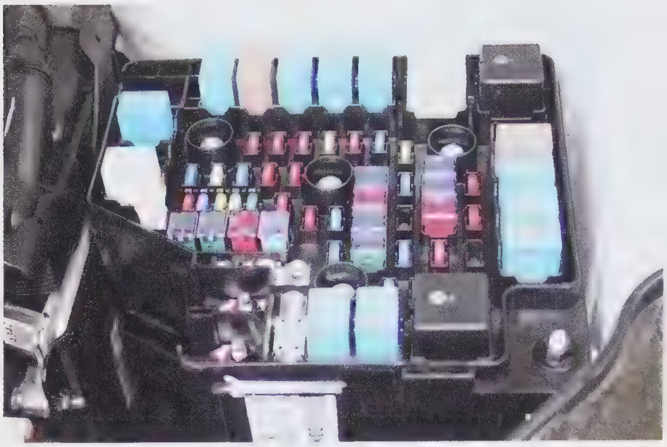


Figure 19-11. *The fuse block is located under the dash, on the side of the dash, or in the engine compartment.*

Motors

Electric motors operate various devices, such as the power windows, power mirrors, and power seats. Reversible motors operate in two directions by reversing power and ground.

Motors that power the windshield wipers, blower, and cooling fan operate in one direction only, are not reversible, and have only one ground and power connector. Typical cooling fan motors are shown in **Figure 19-12**.

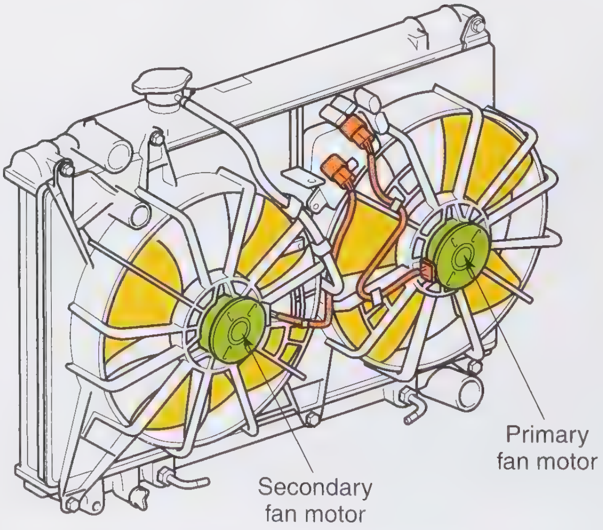


Figure 19-12. *Many vehicles are equipped with two cooling fan motors. (Toyota)*

Basic Electrical Systems

The electrical system of a modern vehicle is a complex web of wires, electrical boxes, and computers. Some of these components may have to be repaired or replaced during the collision repair process. Usually the parts damaged in a repairable vehicle are on the outside, or perimeter, of the vehicle. Underhood parts may be damaged if they are mounted near the radiator support. Underdash electrical parts are usually not damaged in a repairable vehicle. However, air bag deployment will require service of electrical devices in the passenger compartment.

This section explains the construction and operation of various vehicle electrical systems, including the charging and starting, lighting, horn, windshield wiper, and power accessory systems.

Battery, Charging System, and Starting System

The ***battery***, along with the charging system, is the vehicle's source of electrical power. The size and shape of the battery case is matched to the vehicle. The capacity of the battery is a measure of its ability to provide electricity and is rated in amps and volts. A replacement battery should have the same design and capacity as the original battery.

Figure 19-13 shows a battery. Batteries must be properly secured to prevent movement. They are held in place by tie-downs. In many cases, a plastic block bolted to the battery tray acts as a wedge to hold the battery in place. If the battery is not secured properly, it can tip. This could allow a terminal to make contact with metal and cause a short.

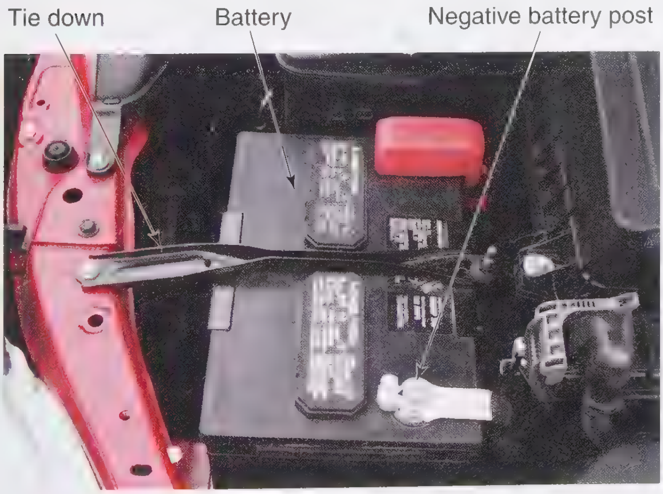


Figure 19-13. *A battery must be properly secured to prevent movement. If not secured, the battery can tip and cause a short.*

The battery has positive and negative terminals. Some batteries have posts for terminals. Other batteries have threaded terminals that accept a bolt.

The positive battery cable is connected from the positive terminal of the battery to the starter or to an electrical connector on the apron. This cable provides the power to the electrical system. The negative cable is connected from the negative battery terminal to the engine block. This provides the return path for electron flow.

The ***alternator*** produces electricity to recharge the battery and provide electricity to various vehicle systems when the engine is running. As the engine spins, it turns a belt that rotates the pulley on the alternator. The alternator pulley turns a rotor inside of a stator. See **Figure 19-14**.

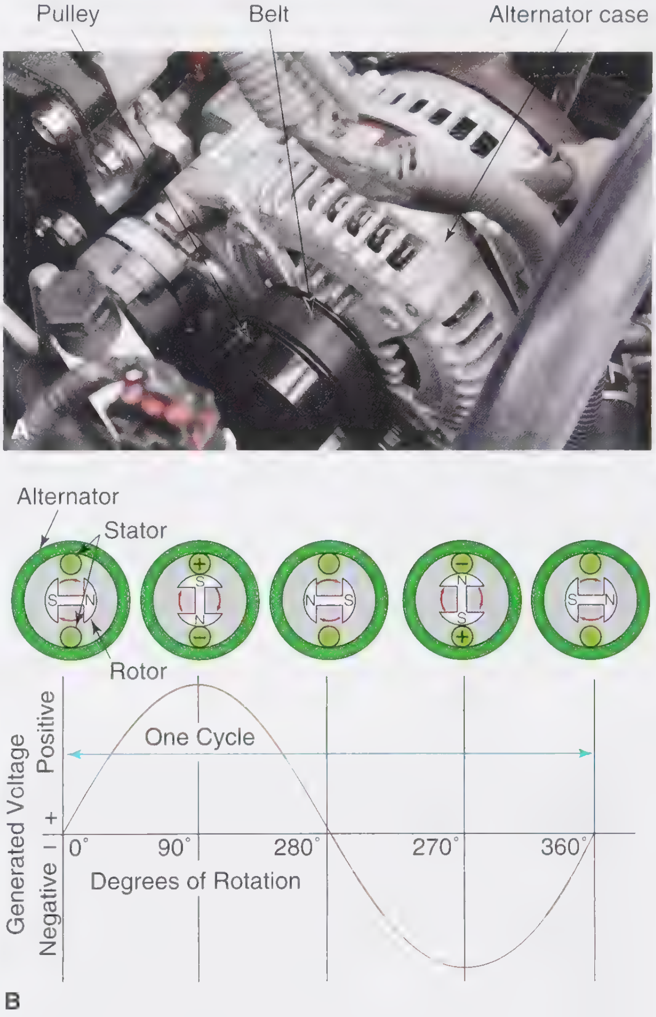


Figure 19-14. *A—An alternator converts the mechanical energy supplied by the engine into electrical energy. B—In an alternator, a rotor spins inside the stator. This rotating magnetic field induces current into the station windings of the stator. As the poles of the rotating magnetic field move across the stationary windings, an output current is generated.*

The rotor is a magnet; the stator is a coil of wire. Rotating the magnet inside the coil of wire produces current. This current is fed to the battery whenever the vehicle is operating. The alternator is held in place on the engine with a bracket. On some vehicles, changing the position of the alternator on the bracket tightens the drive belt.

Lighting System

The lighting system converts electrical energy into light through various bulbs. The lighting system includes switches, wiring, sockets, and bulbs, as well as the housings that contain the bulbs.

There are two types of headlights: ***sealed beam*** and ***replaceable bulb***. A sealed beam headlight is shown in **Figure 19-15**. The sealed beam headlight is held in place with a retaining ring that fits around the headlight. Sealed beam headlights can be high beam, low beam, or a combination. Sealed beam headlights may be either round or rectangular.

The headlight mounting bracket is bolted to a mounting panel with ***aiming screws***. The aiming screws are used to properly position the headlight. This positioning is called ***aiming***. Aiming the headlights orients the lights straight ahead of the vehicle and at the proper height.

A composite headlight, with a replaceable halogen bulb, is shown in **Figure 19-16**. If the bulb burns out, just the bulb can be replaced. The headlight lens is made of plastic or glass. This type of headlight also requires aiming. The headlight assembly is bolted to a headlight mounting panel.

A high intensity discharge (HID) headlight is shown in **Figure 19-17**. The bulb for this headlight contains xenon gas, mercury, and two electrodes. A ballast wired in the HID headlight circuit provides the high voltage, 600V, needed to create an arc in the bulb. Once the bulb is lit, the ballast provides 55V to keep the light on. The light from the HID headlight has a bluish-white cast compared to the light from a sealed beam or halogen headlight.

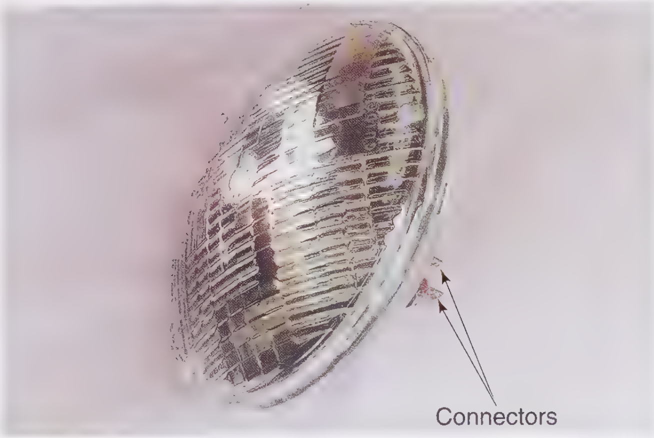


Figure 19-15. *Notice the connectors on the back of this sealed beam headlight.*

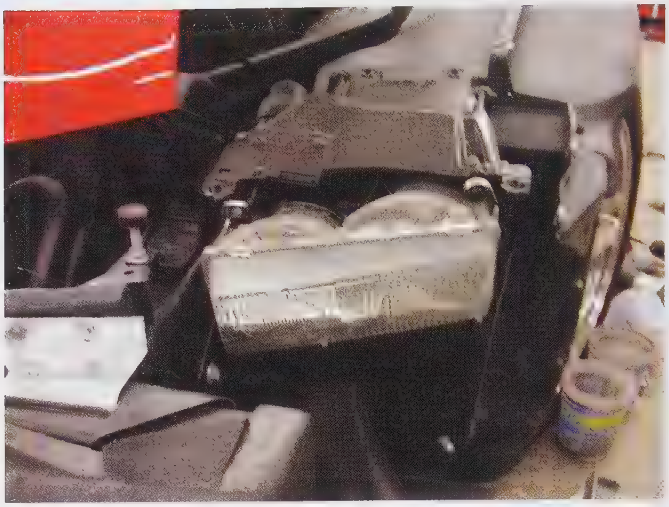


Figure 19-16. *A composite headlight has a replaceable bulb. The bulb is fitted in from the rear of the headlight.*

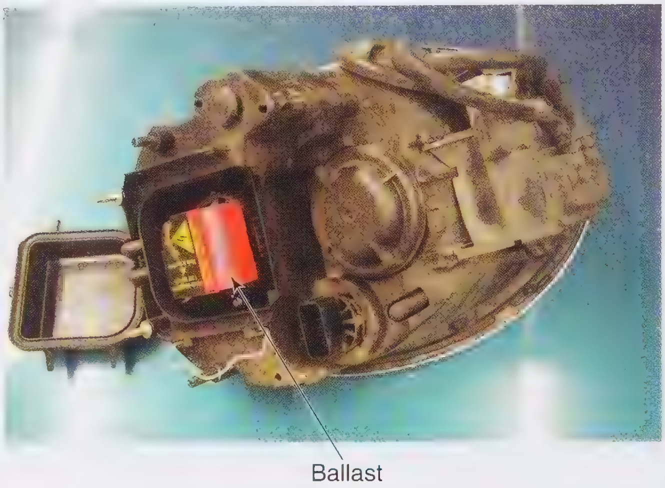


Figure 19-17. *This rear view of an HID headlight assembly shows the ballast. Because the ballast can produce extremely high voltage, precautions must be taken when servicing HID headlights.*

There are a wide variety of ***taillights***, but all taillights have three functions—illumination, stop signal, and backup lights. An example of a taillight is shown in **Figure 19-18**. The taillight assembly consists of a lens, housing, bulbs, and sockets. The taillight contains two or three bulbs. Taillights are usually bolted into place, although some taillights are held in place with thumb screws.

The ***marker lights***, or ***turn signal lamps***, are located in the bumper, header panel, quarter panel, or fender. They consist of a lens, bulb, socket, and housing. In some lamps, each separate lens is replaceable, while in other lamps the lens and housing are in one unit.

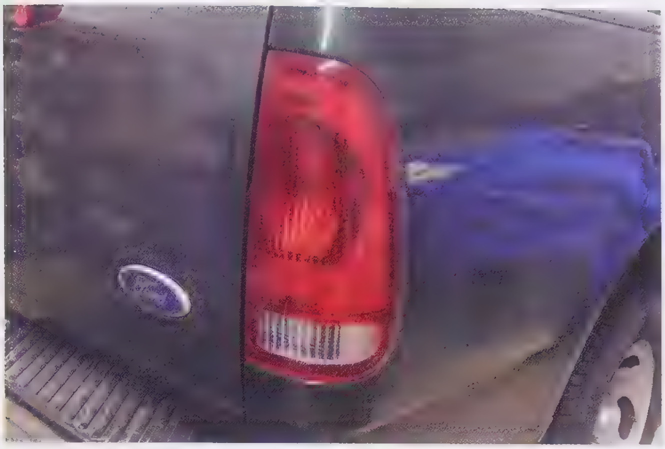


Figure 19-18. *The taillight contains red and clear plastic. The clear plastic area is the backup light. This taillight wraps around the side of this vehicle, so no side marker light is required.*

Side marker lamps are located on the fenders at the front and rear of the vehicle. These lamps alert other drivers to the location of the side of the vehicle. The lamp may be separate or part of a lamp that wraps the front and side, rear and side, or taillight of a vehicle. See **Figure 19-19**.

A switch governs the operation of the lights. Wiring connects the battery to the switch, the switch to the light, and the light to the ground. The light switch is found on the steering column or the dash. The switch has three positions: off, marker lights and taillights only, and marker lights, taillights and headlights. Some vehicles are equipped with a switch that turns on the headlights, taillights and marker lights whenever the ignition is on. A recent safety innovation is daytime running lamps. These lights are switched on automatically when the car is started and remain lit, making the vehicle more visible to other drivers.

In other vehicles, a sensor detects a lower level of light and automatically turns on the headlights, taillights, and marker lights. A switch also controls the turn signals. The turn signal switch is in the steering column and is controlled by a stalk. Pushing the stalk up or down activates the right or left turn signal.

Interior lights are not commonly damaged in a collision. However, the light switch may be damaged by a side impact. The interior lights are controlled by a switch located in the door opening. See **Figure 19-20**. The action of the door shutting against this switch turns off the lights by opening the switch. Opening the door allows the switch to close, which turns on the lights.

Not all vehicles have a door switch mounted in the door opening. In some vehicles, the door switch is in the door latch. When the door is opened, the switch turns on the dome light. When the door is latched, the switch turns off the dome light.

Horn System

The horn is usually mounted on the radiator support, **Figure 19-21**. The horn circuit includes wiring, the horn relay, the horn, and the horn switch.

The horn switch is operated by one or more buttons on the steering wheel. Pushing the button on the steering wheel closes the horn switch. This allows electricity to flow to the horn relay. The relay closes, completing the circuit to the horn. High current then flows through the wiring to the horn. The horn sounds as long as the horn button is pushed.

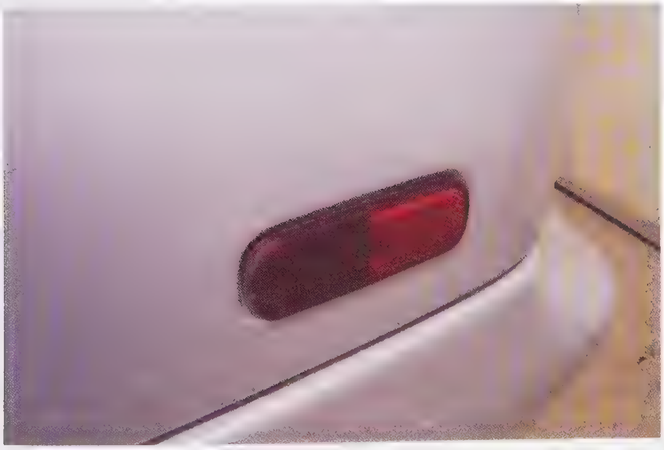


Figure 19-19. *This side marker light is bolted to the quarter panel.*

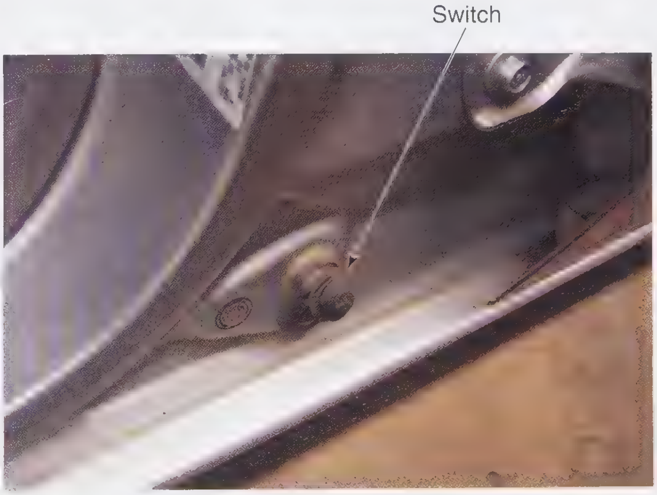


Figure 19-20. *This switch turns on the dome light when the door is opened.*

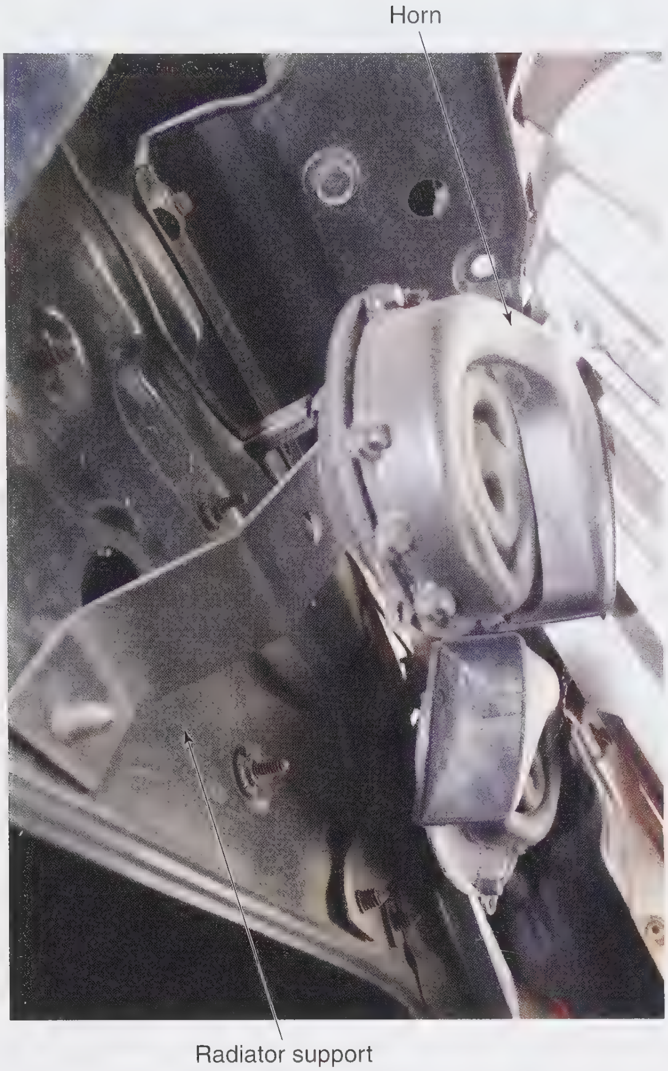


Figure 19-21. *Horns are usually mounted on the radiator support. This forward location makes them susceptible to damage in a collision.*

A car horn is a strong electromagnet that oscillates a flexible diaphragm made of spring steel. Putting a spring steel diaphragm into motion takes a lot of electrical energy. In fact, only the starter uses more electricity than the horn. That is why a relay is needed.

When the horn button is pressed, current flow from the relay supplies the high current to the strong electromagnet that flexes the metal diaphragm to its mechanical limit. Upon reaching its mechanical limit the contact is broken, which momentarily stops the flow of current to the electromagnet. Without current the steel diaphragm relaxes, but only for a moment, because when it returns to its starting point it reestablishes the circuit. The diaphragm is once again flexed by the strong magnet until it again breaks contact. This happens repeatedly at a very high rate setting up an oscillation that can reach 90 decibels.

A ***clockspring*** is a coil that retracts and expands inside its housing as the steering wheel turns. It is called a clockspring because it looks like the mainspring in an old-fashioned wind-up clock. Its function is to maintain electrical continuity for all the components found on the steering wheel such as the driver's air bag, horn switch, and any vehicle controls such as radio, cruise control, heat, and even telephone on some vehicles. All of these circuits run through the clockspring.

Clocksprings are often replaced after airbag deployment as the heat created by the expanding gas during airbag inflation can melt connectors.

Windshield Wiper and Washer Systems

A windshield wiper system is shown in **Figure 19-22**. As the windshield wiper motor's shaft rotates, it moves linkage rods. The linkage rods cause the wiper studs to rotate and move back and forth. A wiper arm is either bolted or fitted onto each stud.

A windshield washer system consists of a fluid reservoir, pump, tubing, and nozzles. The nozzles may be mounted on the hood or the cowl.

Rear window wipers and washers are found on station wagons, vans, hatchbacks, and SUVs. They may be mounted above or below the rear window. The motor for the wiper is usually mounted inside the rear hatch. The washer system has a nozzle above the window or mounted on the wiper arm. The reservoir and pump are located inside the rear quarter panel. The pump and reservoir can be accessed through a door in the interior trim. Plastic tubing connects the pump to the nozzle. The wiper motor and washer pump are controlled by a switch mounted on the dash or the steering column.

Power Accessory Systems

Late-model vehicles are equipped with a variety of power accessories, including power windows, locks, and seats. In addition, many vehicles have power mirrors, a power antenna, and a power sunroof. Although the design of each system is different, they all rely on electric motors or solenoids to move various components.

The ***power window system*** consists of a switch, regulator motor, regulator, and linkages. The regulator moves a linkage, which raises or lowers the window. The linkage consists of either arms or a strap. The switch is located in the door and a master switch can operate all the vehicle's movable windows from the driver's seat. A power window regulator and motor are shown in **Figure 19-23**. There are several other designs.

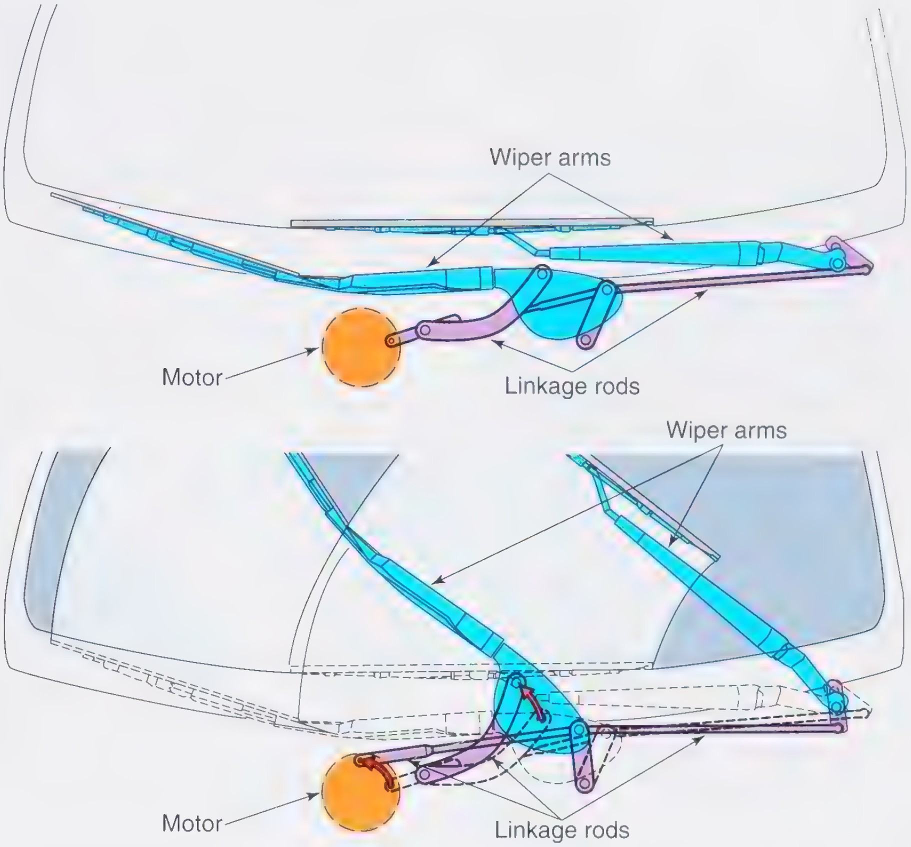


Figure 19-22. *The windshield wiper and linkage rods are mounted on the cowl.*

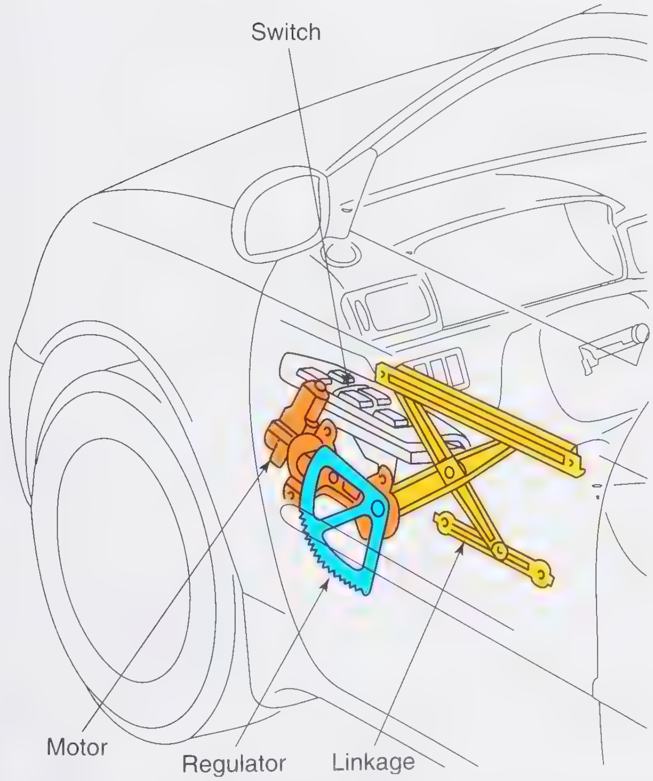


Figure 19-23. *The window regulator motor is mounted inside the door. The motor either moves arms or a strap.*

A ***power door lock system*** uses solenoids to lock or unlock the vehicle's doors. A power door lock system is shown in **Figure 19-24**. The activation can originate from a door lock switch or a remote switch. In some power lock systems, the doors lock automatically when the vehicle reaches a predetermined speed. A power trunk lock or rear hatch lock operates in a similar manner.

A ***power seat system*** uses electric motors to move the seat. The seat can move forward and rearward, as well as up and down. Additionally, the seat back may move forward or backward. Each function requires a separate motor. The power seat system consists of motors, linkage or tracks, and a switch or switches.

A ***power mirror system*** has two motors: one to adjust the left and right positions, and one to adjust the up and down positions. A switch inside the vehicle is used to activate the motors.

A ***power sunroof system*** has a motor, switch, gears, and tracks, as well as drainage tubes. The motor draws the sunroof open or closed along its tracks. A drain at each corner, consisting of a plastic tube that is routed through the pillars, moves rainwater to the underside of the vehicle. Often, the cause of a leaking sunroof is dirt and debris obstructions in the drainage tubes.

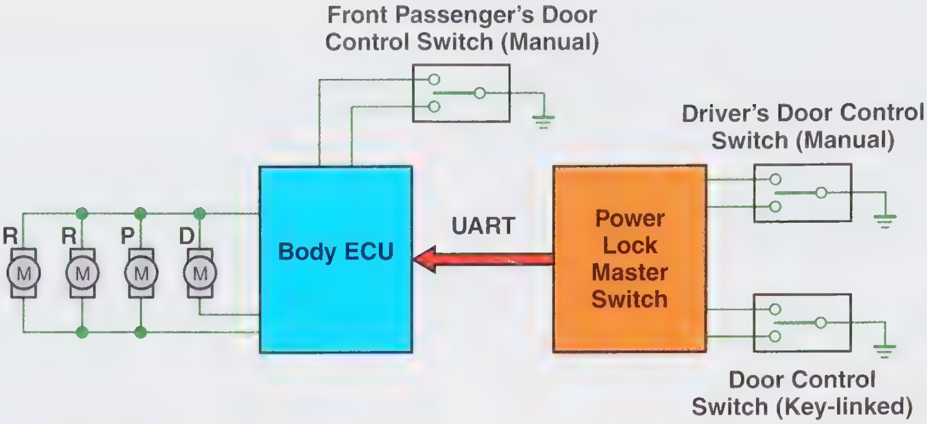

Front Passenger's Door Control Switch (Manual)
Driver's Door Control Switch (Manual)
R
R
P
D
M
M
M
M
Body ECU
UART
Power Lock Master Switch
Door Control Switch (Key-linked)

Figure 19-24. *The power door lock system uses solenoids and switches to lock or unlock the vehicle's doors.*

Pickup trucks may be equipped with a power rear window. The sliding glass in the rear window is operated by a motor located in the back panel of the cab. Vans may have power sliding doors, which are operated by a switch inside the van or by a remote switch.

The ***power antenna system*** consists of a telescoping antenna, motor, and cable. A power antenna has a switch in the radio. Whenever the radio is turned on, the antenna goes up. When the radio is turned off, then the antenna goes down.

A ***rear defroster/demister system*** consists of a conductor grid on the inside of the rear window glass. See **Figure 19-25**. When the heat switch is turned on, the relay closes and the grid heats up. This process warms the surrounding glass and removes condensation or ice. Some systems have a timer that shuts off the system after a predetermined amount of time. **Figure 19-26** shows a schematic of a rear defroster system. A heated windshield operates in the same way. However, instead of a grid, the heating element is a conductive film sandwiched in between the layers of glass. In both cases, the electrical connections must be disconnected before removing the glass.

A recent innovation is windshield wiper deicers. A heating element is built into the glass and is positioned below where the wiper blades rest. This device heats and unfreezes the wiper blades.

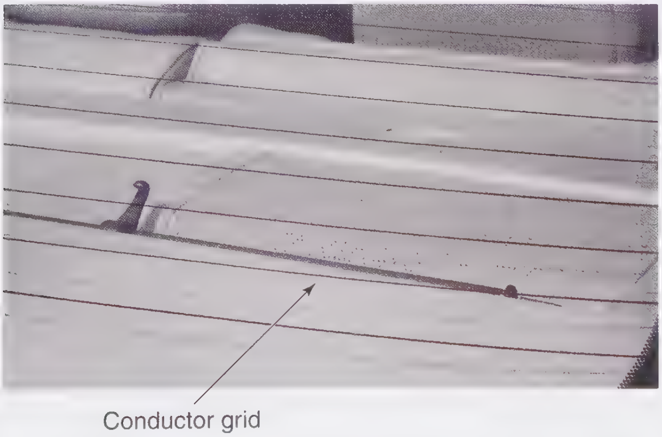


Figure 19-25. *This rear window glass is heated by an electric grid.*

Basic Electrical Tests and Service Operations

To diagnose any electrical system problem, the technician must understand that an electrical circuit must be complete for a system to operate. All the wires

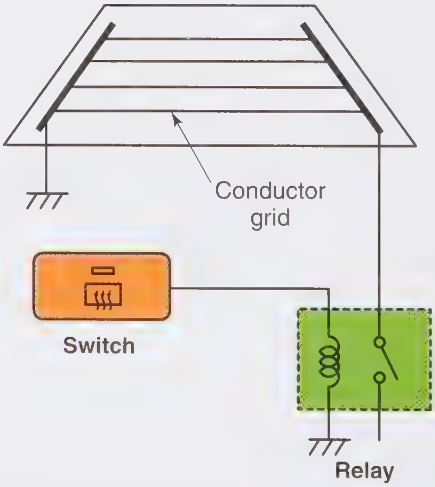


Figure 19-26. *A conductor grid on the inside of the rear window glass warms the surrounding glass and removes condensation or ice.*

must be connected. The connections must be clean and tight, and the ground wires should be attached to bare metal. There must also be a source of power.

Proper diagnosis requires deductive reasoning. The technician must recognize that a problem exists and then work, step by step, to seek a solution to the problem. In a collision repair shop, the most common electrical diagnosis involves determining if current is available to a load, such as a motor or a lamp. If current is available and the load does not operate, suspect that the load is bad. If current is not available, suspect that a fuse, wire, ground, or switch is bad. For example, if all power door locks in a four-door vehicle are on the same circuit with one fuse and only one lock does not work, the fuse is not the problem. Conversely, if none of the locks work, it is not likely that all four solenoids are bad. It is more likely that they are not receiving power. The fuse is the first component that should be suspected.

CAUTION

Do not replace a blown fuse until the cause of the excessive current is determined and repaired.

Using a Test Light

There are two types of test lights used to troubleshoot electrical circuits. A nonpowered test light is used to determine if electricity is present in a circuit. A powered test light is used to check for continuity in a circuit.

NOTE

When using a *nonpowered* test light, make sure the vehicle's battery is charged and power is being fed to the circuit to be tested. Some circuits require that the ignition key be turned to the *on* position.

A ***nonpowered test light*** consists of a probe connected to a 12V bulb and a ground wire. The ground wire is connected to a good ground, such as the bare metal of the vehicle, and the probe is touched against a bare connector or bare wire in the circuit to be tested. If electricity is flowing in the circuit, the bulb in the test light will light. **Figure 19-27** shows a test light in use.

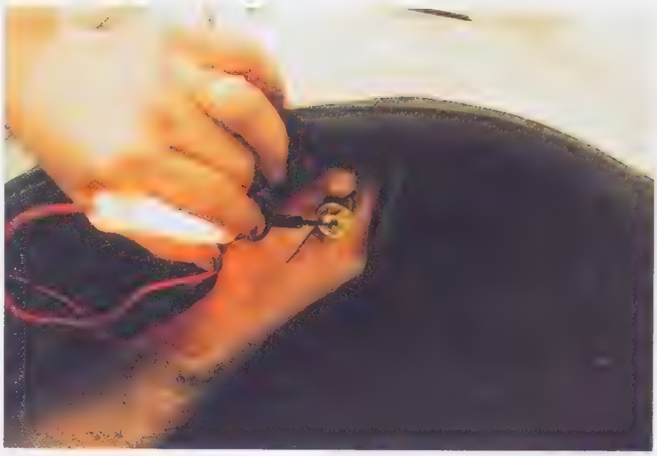


Figure 19-27. *The nonpowered test light has a ground wire that is attached to bare metal. The test light probe is inserted into the socket. If power is available at the socket, the test light will glow.*

If a power window motor does not work, a test light can be used to determine if power is available to the motor. Disassemble the door to uncover the power window motor and wiring, and then disconnect the wiring from the motor. Insert the test light probe into one of the connectors on the wiring, and connect the ground to bare metal on the door. Turn the key so that power is supplied to the switch and the wiring. Move the switch to both the up and down positions. If the test light illuminates when the switch is moved, power is available to the motor and the motor is most likely bad. If the test light does not glow when the switch is moved, it is likely that the wiring, ground, fuse, relay, or switch is bad.

To check a fuse in a circuit with a nonpowered test light, connect the light's ground wire to ground and touch the probe to the power input side of the fuse. The light will glow if there is power available to the fuse. Next, touch the probe to the output side of the fuse. If the fuse is good, the test light will light up. If the light does not glow, the fuse is bad.

To test a switch with a nonpowered test light, connect the ground wire to a good ground and touch the probe to the power input side of the switch. If the test light turns on, power is available to the switch. Next, probe the power output side of the switch with the switch turned on. If the test lamp turns on, the switch is good. If it does not turn on, the switch is bad. A relay can be tested in the same way. First, check to see if power is available to the relay by probing the power input side of the relay. If power is available, turn on the switch and probe the power output of the relay. If no power is available, suspect that the relay or the switch is bad. If further testing reveals that the switch is good, the relay is bad.

A ***self-powered test light***, often called a continuity tester, does not need the vehicle battery for power. Power is provided by a battery located inside the test light. The self-powered test light determines if there is a continuous pathway for electricity between the tester's probes. It is used in the same way as a nonpowered test light, but the power must be off in the circuit when the tester is used.

Additionally, because the continuity tester provides power, it should not be used on electronic systems. The power from the tester may overload electronic components, destroying them.

To use a self-powered test light, touch the probe end of the continuity tester to one end of the wire or component being tested. Be sure to touch a bare wire or a bare connector. Hook the ground clip to the opposite end of the wire or component. If the lamp in the continuity tester glows, there is continuity in the wire or component.

A continuity tester can be used to check for damaged wiring. For example, if a marker lamp does not work, the wiring can be checked for a continuous circuit. The key and light switch should be off. Disconnect the wiring at the lamp, hook up the continuity tester to the connector and find the other end of the wire at a junction box. Hook the ground to the other end of the wire at the junction box. If the bulb in the continuity tester lights, there is a continuous circuit and the wiring is okay.

To test a switch, disconnect the switch from the circuit. Place the probe on the power input connector and hook the ground to the power output connector. If the switch is good, the continuity tester will not light when the switch is turned off, but it will light when the switch is turned to on.

Using a Jumper Wire

A ***jumper wire*** is a length of wire with an alligator clip at each end. A jumper wire serves as a temporary pathway for electricity. Jumper wires often contain a fuse and will stop carrying current if excess current flows through the wire. A jumper wire that lacks a fuse has the potential to carry too much current. Too much current moving through the wire will produce heat and could cause the wire to melt or harm the component the jumper wire is hooked to.

A jumper wire can be used to carry current from a battery to a power window motor in a used replacement door. Before the used door is connected to the vehicle's wiring system, the window cannot be operated. However, the window must be moved down to disassemble the door. Jumper wires can be connected from a battery or battery charger to the power window motor or connected to wiring between the power window switch and the motor. Connect one jumper wire to the positive battery terminal, and another jumper wire to the negative battery terminal. These are called the positive and negative wires. Do not let the positive wire touch the negative wire, as this will create a short circuit. Because the power window motor is reversible, touching the positive wire to one connector on the motor and the negative wire to the other motor connector will cause the motor to turn one way. Reversing the wire placement will cause the motor to turn the other way.

Digital Multimeter

A digital multimeter, or DVOM, can be used to check for voltage, current, and resistance in a circuit. A voltage check will show that the proper amount of electricity is flowing to the component. If the proper amount of electricity is available at a motor but the motor does not work, it can be assumed that the motor is bad and the battery, wiring, fuse, switch, and all other components in the circuit are good.

To check voltage to a motor, hook the red and black leads to the proper locations on the meter and turn the dial to the *volts* setting. Disconnect the wiring connectors at the motor. Do not let the wire terminals touch. If there is only one terminal on the motor, disconnect it. The vehicle's battery should be fully charged, the key should be on (for most electrical circuit tests), and the switch for the circuit should be on. If there are two wires to the motor, attach the black lead to one terminal and the red lead to the other terminal. The DVOM display should indicate battery voltage (approximately 12.6 V). If there is only one wire connected to the motor, touch the red lead to this wire and touch the black lead to a good ground. Again, the DVOM display should read approximately 12.6 V.

Higher-than-normal resistance, due to corrosion or damage, will prevent the proper flow of electricity through a component or circuit. A voltage drop test is used to see if the component or circuit has excessive resistance. Voltage drop is the voltage measured.

To perform a voltage drop test on a switch, begin by measuring the voltage at the power input side of the switch. Then, with the switch turned on, measure the voltage at the power output side of the switch. The difference between the voltage on the input side and that on the output side should be less than 0.2 V. If it is not, there is excessive resistance in the switch. An easier way is to measure across the switch. The result is the same, but the process is more direct.

To test a wire, check the voltage at one end of the wire and compare it to the voltage at the other end of the wire. Any drop in voltage indicates a problem with the wiring.

When set to *ohms*, the DVOM will measure resistance in a circuit. If it is a continuous circuit, the DVOM will read less than 0.1 Ohm. If the circuit is open, there is no continuity and the DVOM will read infinite resistance. See **Figure 19-28**. Check switches and relays with a DVOM in the same way as when using a continuity tester. Always disconnect power to the switch or relay before testing.

To check the level of current using a DVOM, you must "break into" the circuit so the current passes through, and is measured by, the meter.

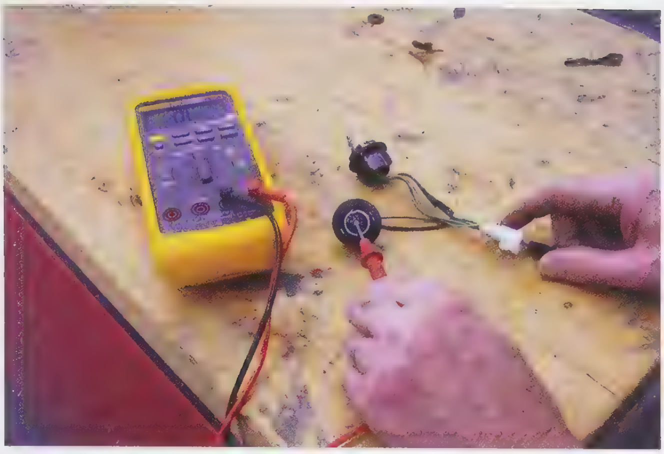


Figure 19-28. *A digital voltmeter DVOM is used to check a bulb circuit for continuity. There is no continuity in this circuit.*

Using Wiring Diagrams

A wiring diagram is a "road map" of the vehicle's circuits. See **Figure 19-29**. It can be a useful tool when diagnosing an electrical problem. The technician can visually trace the path of electricity through a circuit. Wiring diagrams may be available on the Internet, in repair manuals, and from the manufacturer.

The diagram may show where wires are routed and how electrical components are arranged. The wiring diagram also lists the color and size of the wires that lead to motors, switches, and other electrical components.

Color wiring diagrams show the actual colors of the wires. For black-and-white wiring diagrams, the color of the wires is indicated in a key on the diagram itself.

In most wiring diagrams, symbols are used to represent various electrical components. Some of the most common electrical symbols are shown in **Figure 19-30**.

Wiring Repairs

Cut or broken wires are often spliced during repair. Splicing is the joining together of two or more wires by uniting or interweaving the strands. The goal of any repair is to join the wires together so they will conduct

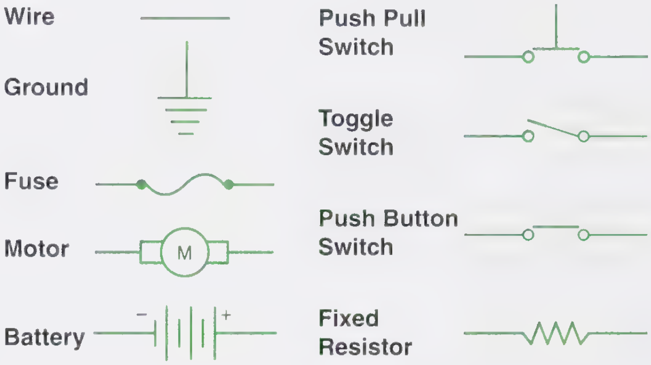

Wire
Push Pull Switch
Ground
Toggle Switch
Fuse
Push Button Switch
Motor
M
Battery
–
+
Fixed Resistor

Figure 19-30. *These symbols are found on wiring diagrams and schematics.*

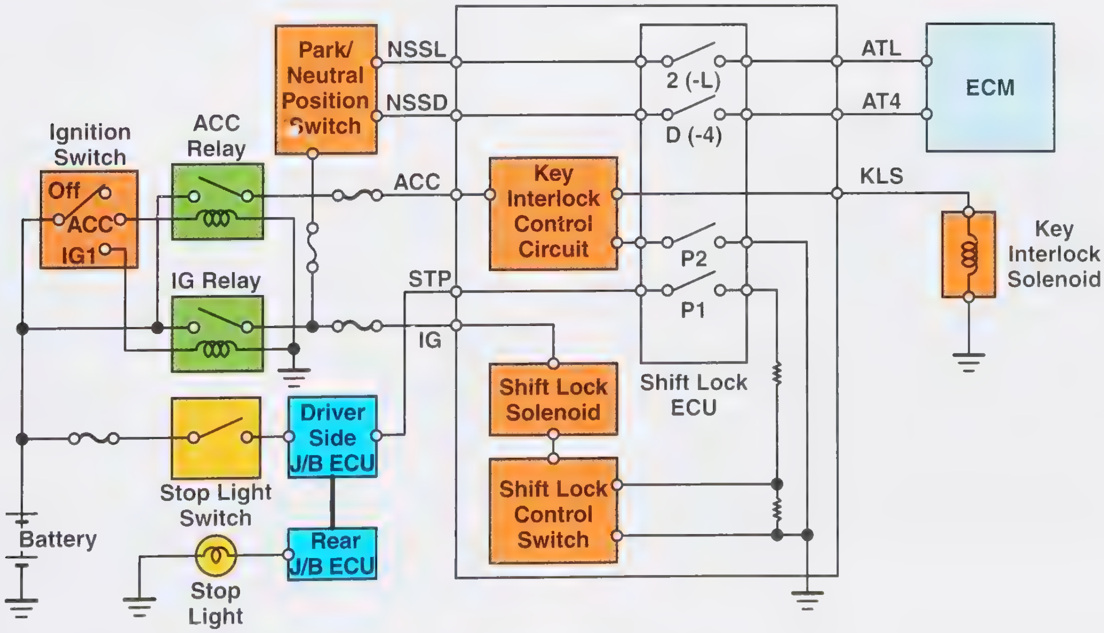

Park/ Neutral Position Switch
NSSL
NSSD
ATL
AT4
ECM
2 (-L)
D (-4)
Ignition Switch
ACC Relay
Off
ACC
IG1
ACC
KLS
Key Interlock Control Circuit
P2
P1
Key Interlock Solenoid
IG Relay
STP
IG
Shift Lock Solenoid
Shift Lock ECU
Driver Side J/B ECU
Stop Light Switch
Shift Lock Control Switch
Battery
Rear J/B ECU
Stop Light

Figure 19-29. *This schematic shows a small section of a wiring drawing.*

electricity as well as an undamaged wire. The wires must be joined tightly. The joint must be weatherproof. Water and oxygen can cause corrosion in the splice joint. Corrosion increases resistance and inhibits current flow.

Joining wires requires that the insulation be stripped from the wires. Use wire strippers to cut and remove insulation as shown in **Figure 19-31**. When stripping the insulation, be careful not to cut the wire. An unintended cut in the wire can negatively affect current flow. The cut does not have to go all the way through either. A nick or partial cut will inhibit current flow.

There are two ways to repair a wire. One method requires the use of solder. The other involves using solderless crimp connectors.

To solder wires together, first slip heat-shrink tubing over one of the wires. Next, strip about 1" of insulation from each wire. Twist the wires together. Do not allow the wire ends to touch the insulation. Heat the soldering iron and coat the tip with rosin core solder. Then heat the twisted wires with the tip of the soldering iron. Melt solder on the wire using only the heat from the wire, not the iron. See **Figure 19-32**. Coat all the twisted wires with solder. Next, slide the heat-shrink tubing over the splice. Shrink the tubing with heat from a heat gun.

To use a solderless crimp connector, strip about 1/2" of insulation from the end of each wire. Twist stranded wire before inserting it into the insulated connector. Slip one wire into each end of the crimp connector. Then, crimp the connector to join the wires. Heat the plastic slip-on sleeve to create an airtight connection. Check the connection by gently tugging on the wires. See **Figure 19-33**. Crimping has become the preferred method of joining wires because vibration does not weaken the joint.

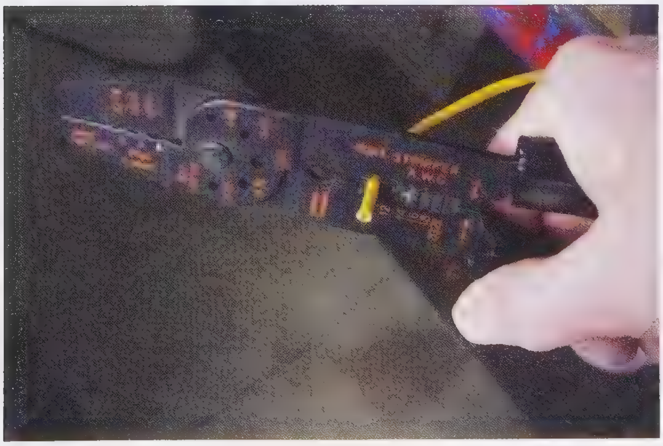


Figure 19-31. *Match the wire size to the stripper grooves. The grooves are smaller than the diameter of the plastic coating. The sharp edge on the inner part of the grooves will slice away the insulating coating.*

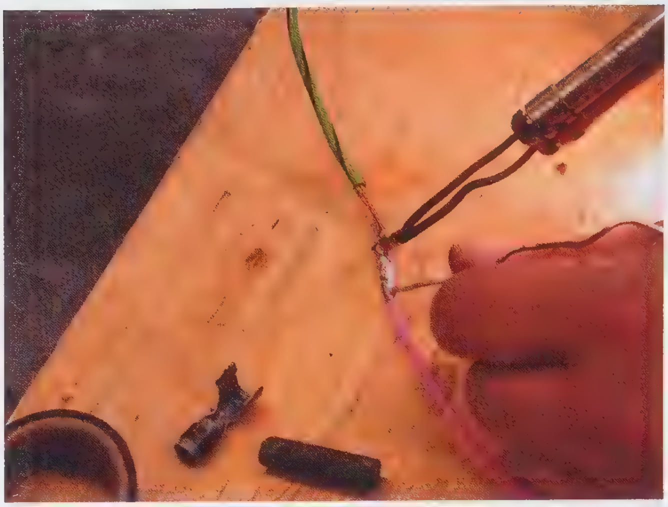
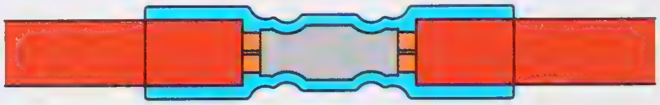


Figure 19-32. *Heat the wires with the tip of the soldering gun and melt rosin core solder on the heated wires. Do not heat the solder and drip it onto the wires.*



Splice after crimping

Figure 19-33. *This illustration shows a solderless connector. The wires are stripped before insertion in the connector. The connector is crimped and then heated.*

Electrical System Service

Few things are as frustrating as finding and repairing an automotive electrical problem. The key is having a logical and systematic plan. The following are basic procedures used in testing and replacing electrical components.

Battery and Alternator Service

NOTE

The vehicle's clock, radio, and computers may all have memory that is maintained by battery power. Disconnecting the battery wipes out the memory on these devices. To avoid this problem, a memory saver can be connected to the vehicle's lighter or auxiliary 12-volt outlet before the battery is disconnected. A 9-volt battery in the memory saver maintains the memory while the vehicle's 12-volt battery is disconnected.

A battery can be damaged in a collision. **Figure 19-34** shows the most common type of battery damage—a cracked case. A cracked battery case cannot be repaired. If a crack is present, the battery must be replaced. Batteries also wear out. A worn out battery will not hold a charge.

WARNING

Always wear safety glasses when connecting or working on a battery. Do not create sparks. A battery produces hydrogen gas. This gas can explode if a spark is created around the battery. The resulting explosion may cause the battery case to shatter, injuring anyone in the way.

A dirty battery should be cleaned. A mixture of baking soda and water can be used to clean the battery terminals and the case. The baking soda neutralizes battery acid. Corrosion on the terminals can be removed with a wire brush. Battery cables can also corrode and deteriorate with age. Replace loose or corroded cables by unbolting the cable and installing a new one.

Dead batteries are common in body shops. When charging a battery to start a vehicle, hook up the battery charger to the battery terminals and set the battery charger for 40–60 amps. Turn on the charger and allow the battery to charge for a maximum of thirty minutes. Then disconnect the charger and start the vehicle.

WORKING GREEN

Batteries that are not recycled end up in landfills where they can leak toxic materials into the environment. The EPA states that 90% of automotive batteries are recycled.

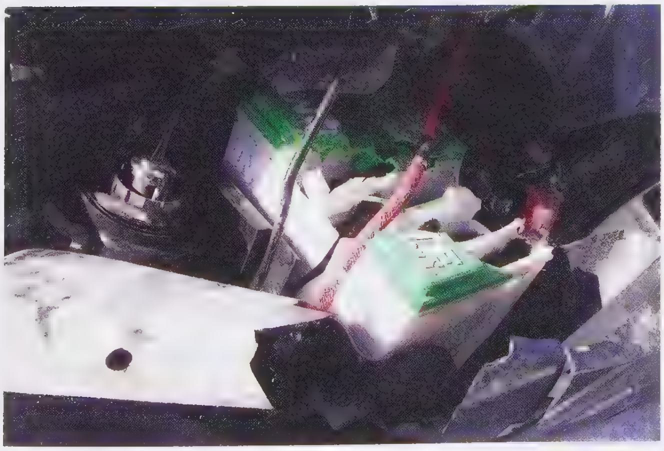


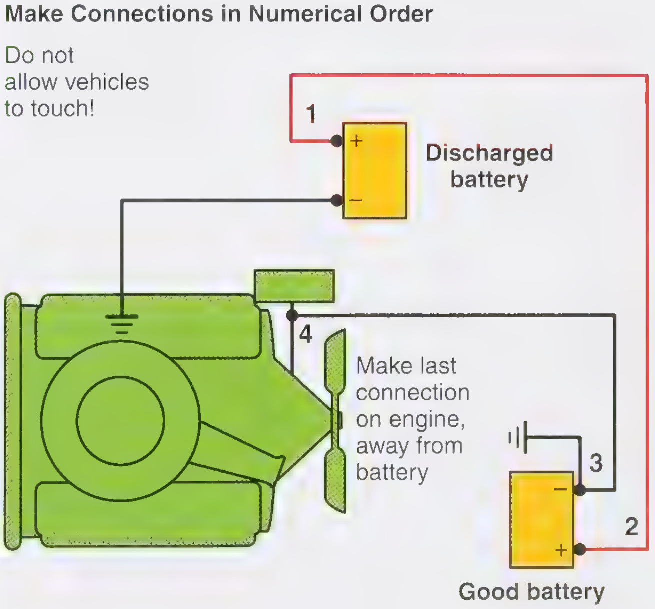
Figure 19-34. *The force of a collision knocked this battery loose.*

To jump start a vehicle, use the sequence shown in **Figure 19-35**. First, clamp one end of the red cable to the positive terminal of the dead battery. Then clamp the other end of the red cable to the positive terminal of the good battery. Next, connect one end of the black cable to the negative terminal of the good battery. Finally, connect the other end of the black cable to the engine block or frame of the vehicle with the dead battery. Start the vehicle with the dead battery and disconnect the wires in the reverse order of installation.

On a front-wheel-drive vehicle, a side impact on the right front corner of the vehicle may move the lower frame rail enough to damage the alternator pulley. A damaged pulley will wobble. On a rear-wheel-drive vehicle, an impact above the bumper may be severe enough to damage the alternator pulley or crack the alternator case. If the pulley or case is damaged, replace the alternator. **Figure 19-36** shows a damaged alternator.

Lighting System Service

Lighting system components are often damaged in a collision. Damage to lights may be obvious, such as a broken lens, or inconspicuous, such as a broken wire or socket. A broken wire may not be easily accessed. A front impact can damage the motor or linkage in a retractable headlight system.



Make Connections in Numerical Order
Do not allow vehicles to touch!
1
+
−
Discharged battery
4
Make last connection on engine, away from battery
3
−
2
+
Good battery

Figure 19-35. *Connect the red jumper cable to the positive post of the dead battery then to the positive post of the good battery. Connect the black jumper cable to the negative post of the good battery and then to a good ground on the engine of the dead vehicle.*

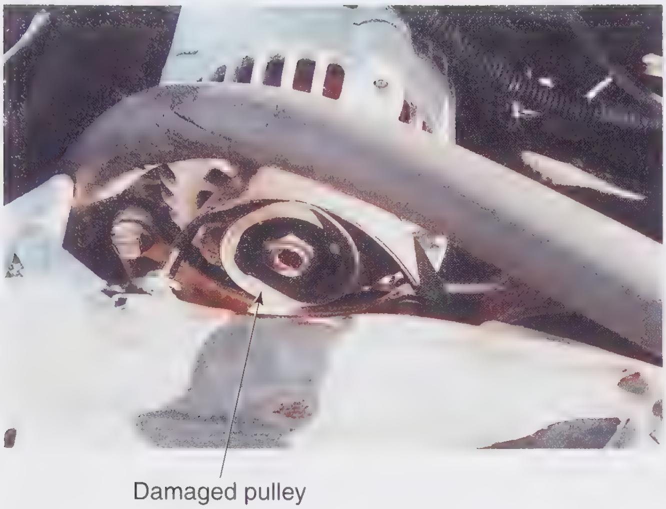


Figure 19-36. *The pulley is bent on this damaged alternator.*

NOTE

Retractable headlights have a manual crank to raise the cover or headlamp if the motor does not function.

Composite headlight assemblies include the lens, mounting bracket, replaceable bulb, and aiming adjusters. Damage to the headlight assembly includes a broken lens or mounting bracket. The assembly is unbolted from the vehicle.

A sealed-beam headlight consists of one or two filaments, a reflector, and a lens in an airtight assembly. It is held in a cup by a retaining ring. The cup, headlamp, and retaining ring are held to the mounting panel by a spring and aiming screws. Any of these components can be damaged in a collision and should be replaced.

Taillights are often damaged when a vehicle is backed into an obstruction. A damaged taillight is shown in **Figure 19-37**. Damage to marker and turn signal lights can range from a cracked lens to a damaged wire or socket.

The door switch for the interior lights can be located on the cowl or center pillar. The distance between the door and the cowl or pillar is important. If the distance is too great, the door cannot push the switch far enough to turn off the lights. This problem arises when a pillar or cowl is pushed in during an accident.

Turn on the lights to check for proper operation. If the bulb does not work, use a test light or a DMM to determine if power is available at the bulb connector. The battery must be connected and charged and the light switch must be on. If power is not available, check the wiring, fuse and switch. If power is available, the bulb is damaged or burned out.

If the bulb is damaged or burned out in a composite headlight assembly, just the bulb can be replaced. Usually, the bulb is taken out from the rear of the headlight assembly. This may require the removal of some underhood parts.

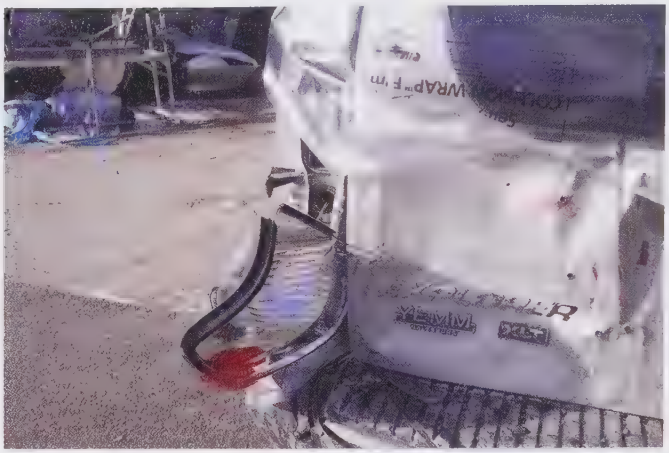


Figure 19-37. *A rear impact knocked the taillight out of this SUV.*

Many bulbs fit into sockets. The sockets may be installed inside a lamp housing. See **Figure 19-38**. Some bulbs can be removed by turning the bulb a quarter turn and then pulling it out of its socket. Other bulbs are removed by simply pulling them straight out of their sockets.

Aiming Headlights

Headlight aiming levels the headlights and points them straight ahead. Accurate headlight aiming determines how much of the road the driver can see at night, an important safety factor. **Figure 19-39** shows the adjustment of aiming screws on one type of composite headlight. The top screw adjusts the vertical position

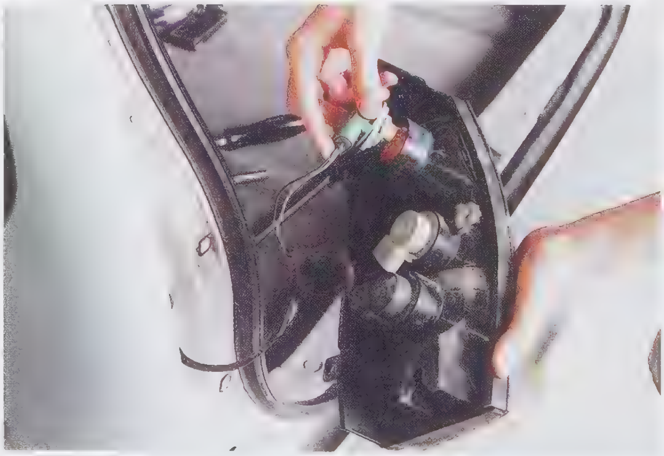


Figure 19-38. *Taillight bulb sockets are removed from the housing by twisting to the proper orientation. When replacing the sockets, align the protruding knobs on the socket with the matching notches in the taillight fixture.*

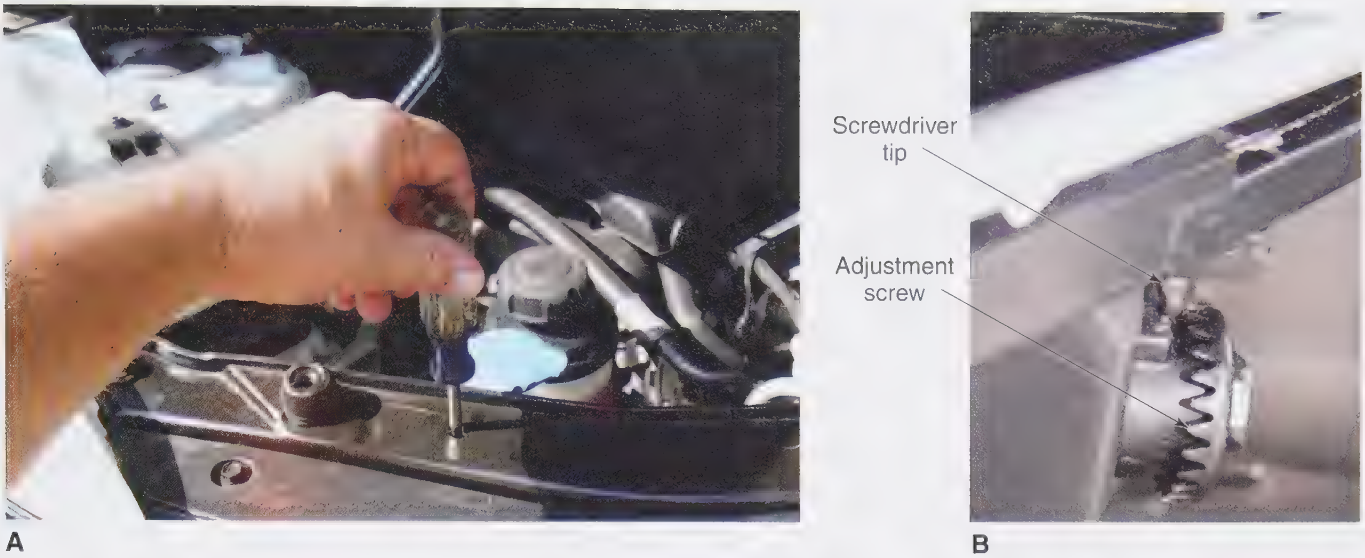


Figure 19-39. *A—Composite headlight adjustment screws are generally found under the hood. B—There are two screws for each assembly, one for horizontal adjustment and one for vertical adjustment.*

(up and down) of the light, and the bottom screw adjusts the horizontal position (left or right). A Torx or Phillips screwdriver may be required to turn the aiming screws on some vehicles. For all the aiming methods that follow, the vehicle must be parked on a level surface.

The most common way to aim and adjust headlights is to project the beam on a wall. The vehicle should be positioned on a level floor, square to the wall, and 25' away. Measure the distance between the headlights and the height of the headlights above the floor. Use the measurements taken from the vehicle to mark the headlight height and the distance between the lights on the wall. Turn the headlights on and observe how the light beam from each headlight hits the marks on the wall. Adjust the headlight to move the beam into alignment with the marks on the wall. **Figure 19-40** shows how to position a vehicle and make the marks on the wall to aim the headlights.

Another way to aim composite headlights is with an aiming tool, **Figure 19-41**. The aiming tool has bubble levels for vertical and horizontal readings. The idea is make adjustments to center the bubble. Each headlight has vertical and horizontal aiming values molded into headlight lens. The aiming values may state 19 V and 12 H. The V stands for vertical and the H stands for horizontal. Suction cups are used to hold the aiming tool to the headlight. The V and H values are zero for flat-faced sealed-beam headlights. The headlight adjusting screws are turned to center the bubbles in the adjusting tool.

On older vehicles, the aiming tool is fitted onto projections on the headlight, and the aiming values are entered into the aiming tool by turning dials. The

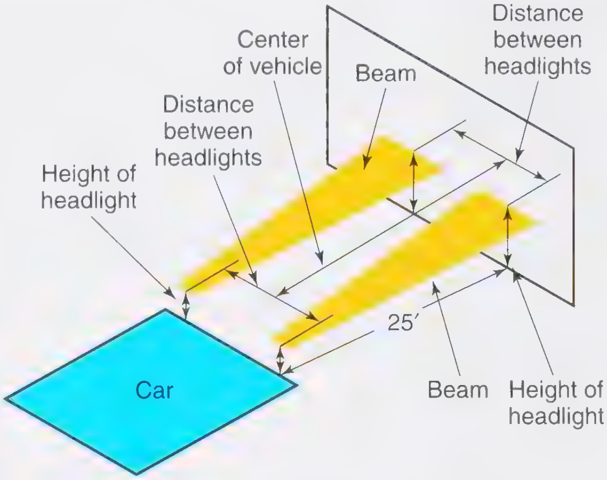


Figure 19-40. *The vehicle should be 25' away from the wall when checking headlight aim.*

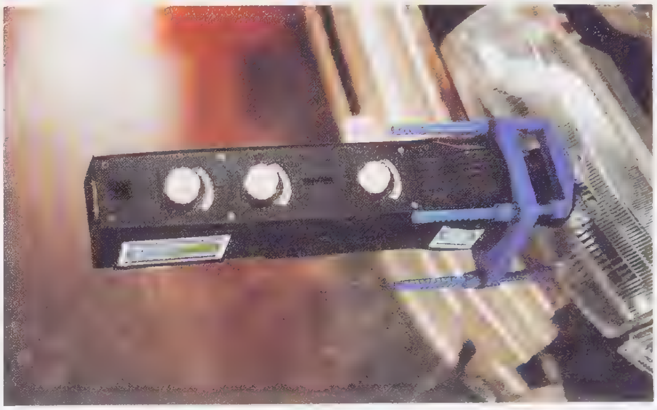


Figure 19-41. *This headlight aiming tool is attached to the headlight with suction cups.*

adjustment screws on the headlight are then turned until the bubbles in the aiming tool are centered. The aiming tool may also be used on flat-faced sealed-beam headlights.

Other types of composite headlight assemblies have integral vertical and horizontal bubble gauges, and no aiming tool is necessary. The adjustment screws are turned to center the bubble in each of the gauges.

Horn Service

A front impact can damage a horn. If the horn does not operate, check for power at the horn. The parts most likely to be damaged are in or near the area of impact. Nevertheless, check parts that are easiest to access, too. If power is not available to the terminal at the horn, check the fuse first. Next check the relay to see if power is available to it. Then check the operation of the relay and the switch. Replace any nonfunctional parts. If power is available to the horn but the horn still does not operate, replace it.

Windshield Wiper and Washer Service

Collision damage to the front wiper motor is unlikely due to its location on the cowl. However, wiper arms may need to be removed during many types of repairs.

A wiper arm may be held in place on a splined shaft with a nut or bolt. See **Figure 19-42A**. After removing the nut or bolt, grab the base of the wiper arm and slide the arm off the splines. The arm may have an attached windshield washer hose. If so, disconnect the hose before removing the arm.

To reinstall the wiper arm, reconnect the windshield washer hose first. Then slide the wiper arm onto the splined shaft. See **Figure 19-42B**. When at rest, the wiper should be located near the bottom of the windshield. After installing the wiper arms, operate the wipers. Check to see that the wipers stop at the A pillar. If necessary, reposition the wiper arm.

CAUTION

Do not operate the windshield wiper motor without the wiper arms attached.

Rear wiper replacement is similar to windshield wiper arm replacement. The rear wiper arm is unbolted then pulled from the splined shaft on the motor. The motor is bolted or riveted to the frame of the rear hatch. Disconnect the wire terminal at the motor. Unbolt or drill out the rivets to remove the motor. If the rear hatch must be replaced, but the wiper and motor can be reused, re-install them on the replacement rear hatch.

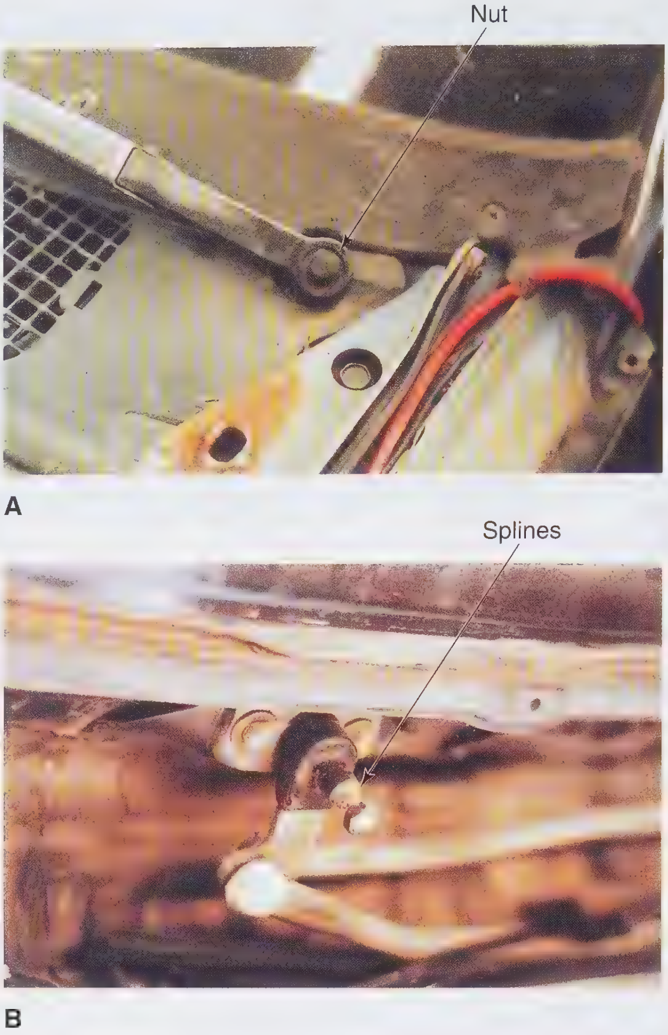


Figure 19-42. *A—This windshield wiper is held in place with a nut. B—The replacement wiper arm will slide onto the splined shaft and be fastened with a nut.*

Power Accessory Service

Power accessories are sometimes damaged during a collision. For example, an impact on a door can damage the power window motor, regulator, or linkage, as well as the power door lock. Power mirrors are often broken when a vehicle is driven too close to an obstruction, such as a garage door opening. A side impact can also cause damage to a power mirror. A rollover can damage a sunroof or the motor. A damaged sunroof or misaligned roof may cause the sunroof to bind. An impact on the quarter panel may damage the power antenna assembly.

To find the cause of a problem when a power window, lock, or mirror will not work, check for voltage at the switch input. This is done by probing the connector with the red lead of a DMM while the black lead is connected to a good ground. If power is available to the switch, check to see if power is passing through the switch.

Probe the output lead in the switch with the switch turned to the "on" position. If power is available out of the switch, the switch is operating correctly. If not, the switch contacts may be corroded. Cleaning the contacts may make the system operate. A common problem with the driver's door power window switch is that coffee or soda spilled on the switch can cause corrosion.

To check a motor, verify that voltage is available at the motor. Connect the red meter lead to one of the motor terminals. Connect the black lead to ground and operate the switch. If power is available at the motor, the motor might be bad. Remove the motor and use jumper wires to connect battery voltage to the motor.

Motors and solenoids may be pop-riveted in place. To remove a riveted motor or solenoid, first remove the electrical connection. Then, use a punch to knock out the rivet mandrel. Select a drill bit slightly larger than the hole in the rivet and drill the rivet out to free the motor from the mounting. Finally, disconnect the motor from the linkage and remove the motor.

To install the motor, first connect the linkage and then rivet the motor in place. Hook up the electrical connector and test the motor for proper operation. On power windows, route the wire so that it does not interfere with window operation.

Summary

- An atom consists of protons, neutrons, and electrons.
- Electricity is created when electrons move from one conductor atom to an adjacent conductor atom.
- Electrical current is the flow of electrons. It is measured in amperes.
- Electrical systems consist of a power source, load, and electrical conductors.
- Power is measured in volts, current in amps, and resistance in ohms.
- A complete circuit and continuity is required for current flow.
- A short circuit, or short, occurs when the current takes an unintended pathway. One example of a short circuit is when a bare wire from one circuit touches a bare wire from a different circuit.
- There are several separate circuits in a vehicle. These circuits are used to power various electrical motors, bulbs, and solenoids.
- A DVOM is used to check switches, relays, motors, bulbs, and sockets.

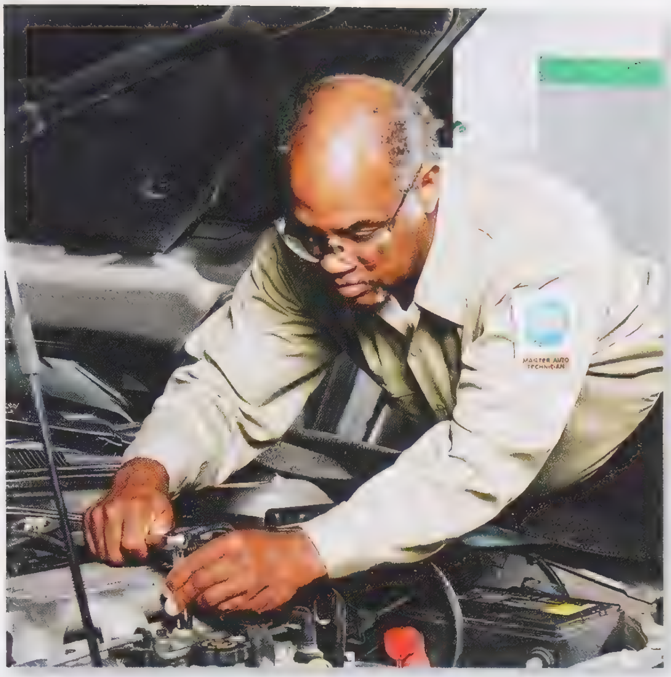
Review Questions

Please do not write in this textbook. Place your answer on a separate sheet of paper.

1. All matter is made of atoms. An atom consists of ______, ______, and ______.
2. A(n) ______ has a positive charge, a(n) ______ has a negative charge, and a ______ is electrically neutral.
3. The description of electricity is based on ______ and ______.
4. Electrical current is measured in ______.
5. Electricity is created when electrons move from one conductor atom to an adjacent conductor atom. For electrons to flow there must be a continuous pathway. This continuous pathway is known as a complete ______.
6. Resistance to electron flow in a conductor is measured in ______.
7. All electrical circuits consist of a power source, a load, and electrical conductors that connect the source to the load. True or False?
8. A series circuit has only one path for electricity to flow through. A parallel circuit has more than one path for the electricity to flow through. True or False?
9. ______ show the pathways electricity can take when flowing from one battery terminal, through a circuit, to the other battery terminal.
10. In most automotive circuits, the power flows from the battery through the load to ______. The ______ completes the circuit, allowing the electrons to return to the battery.
11. When a switch is off, the circuit has an open. True or False?
12. A reversible motor works in one direction only. True or False?
13. The high intensity discharge (HID) headlight contains xenon gas, mercury, and two electrodes. True or False?
14. If electricity is flowing in the circuit, the bulb in the ______ will light.
15. A self-powered test light, often called a continuity tester, determines if there is a continuous pathway for electricity between the tester's probes. True or False?
16. Headlight aiming levels the headlights and points them straight ahead. Describe one of the ways headlights can be adjusted to accurately aim the headlights.
17. A cracked case on a battery can be repaired with plastic welding. True or False?

ASE-Type Questions

1. Which of the following will cause an open?
   (A) A broken wire.
   (B) A blown fuse.
   (C) A melted fusible link.
   (D) All of the above.
2. A DVOM is connected to a circuit to measure current flow. The meter reads OL. Technician A says that there is continuity in the circuit. Technician B says that there is no continuity. Who is right?
   (A) A only.
   (B) B only.
   (C) Both A and B.
   (D) Neither A nor B.
3. A ______ is a magnetic switch that uses a low-voltage signal from a remote location to control the on-and-off operation of a high voltage circuit.
   (A) magneto
   (B) relay
   (C) fusible link
   (D) diode
4. Power is available to the input side of a switch. Power is not available after the output side of the switch when the switch is turned on. Technician A thinks the switch is good. Technician B thinks the switch may be bad or corroded. Who is right?
   (A) A only.
   (B) B only.
   (C) Both A and B.
   (D) Neither A nor B.
5. A continuity check of a windshield wiper circuit gives a result of 0 ohms on the DVOM. Technician A says that there is continuity from the power source to the wiper motor. Technician B says that there is no continuity. Who is right?
   (A) A only.
   (B) B only.
   (C) Both A and B.
   (D) Neither A nor B.
6. A continuity check is used to check for ______.
   (A) a complete circuit
   (B) a short
   (C) ground
   (D) All of the above.
7. A wire will be spliced with solder. Technician A wants to melt the solder with the soldering iron. Technician B wants to heat the wires with the soldering iron and use the heat of the wires to melt the solder. Who is right?
   (A) A only.
   (B) B only.
   (C) Both A and B.
   (D) Neither A nor B.
8. Which type of battery can be used to maintain memory when the vehicle's battery is removed?
   (A) 6 volt.
   (B) 9 volt.
   (C) 12 volt.
   (D) 24 volt.
9. Technician A fast charges a dead battery for sixty minutes. Technician B fast charges a dead battery for 100 minutes. Who is right?
   (A) A only.
   (B) B only.
   (C) Both A and B.
   (D) Neither A nor B.
10. As the result of an impact, an alternator pulley wobbles. Technician A wants to replace the pulley. Technician B wants to repair the pulley. Who is right?
    (A) A only.
    (B) B only.
    (C) Both A and B.
    (D) Neither A nor B.
11. To jump-start a vehicle, Technician A says to clamp one end of the red cable to the positive terminal of the dead battery. Technician B says to clamp the other end of the red cable to the positive terminal of the good battery. Who is right?
    (A) A only.
    (B) B only.
    (C) Both A and B.
    (D) Neither A nor B.
12. Which of the following electrical components is most likely to be damaged by a front end collision?
    (A) Wiper motor.
    (B) Power mirror.
    (C) Battery.
    (D) Headlight.
13. A windshield wiper arm is held in place on a splined shaft with a nut or a bolt. After removing the nut, Technician A says to grab the base of the wiper arm and slide the arm off the splines. Technician B says to check for an attached washer hose and to disconnect that too. Who is right?
    (A) A only.
    (B) B only.
    (C) Both A and B.
    (D) Neither A nor B.
14. The first step in removing a power window motor is to:
    (A) disconnect the electrical wires.
    (B) disconnect the linkage.
    (C) unbolt the motor.
    (D) drill out the rivets.



Chapter 20

Brakes

Objectives

After studying this chapter, you will be able to:

- Understand the function of the brake system and its component parts.
- Identify brake system wear and damage.
- Remove and replace damaged or worn parts.

Technical Terms

anti-lock brake system (ABS)
bleeder valve
electronic stability control system (ESC)
friction
hygroscopic
metering valve
Pascal's law
power brakes
pressure-differential valve
proportioning valve
traction control system (TCS)
tubing flare tool
wheel lockup

Introduction

The brake system is used to slow and stop a vehicle. As the driver pushes on the brake pedal, fluid pressure in the system applies the brake mechanisms located at each wheel, slowing and stopping the vehicle. In addition to the conventional brake system, all vehicles are equipped with a parking brake, which is used to hold a stationary vehicle in place.

Most late-model vehicles are equipped with an ***anti-lock brake system (ABS)***.The ABS allows the driver to maintain control of the vehicle during panic stop situations. Some vehicles also have a ***traction control system (TCS)*** or an ***electronic stability control (ESC) system***. These systems work with the ABS to improve vehicle safety. The TCS aids when driving on a slick roadway by preventing wheel spin when a tire loses traction. The ESC system helps prevent loss of control during emergency maneuvers.

This chapter explains the operation and repair of the brake system and related components. Brake system components can be damaged in a collision. If the brake system is damaged, other mechanical components, such as suspension and steering parts, may also be damaged.

Brake System Operation

Brake system operation is based on the principles of hydraulics and friction. See **Figure 20-1**. The major hydraulic components of the brake system are the master cylinder, brake fluid, and brake lines. The friction components are the disc or drum brake assemblies. The mechanical system includes the emergency brake handle and cables.

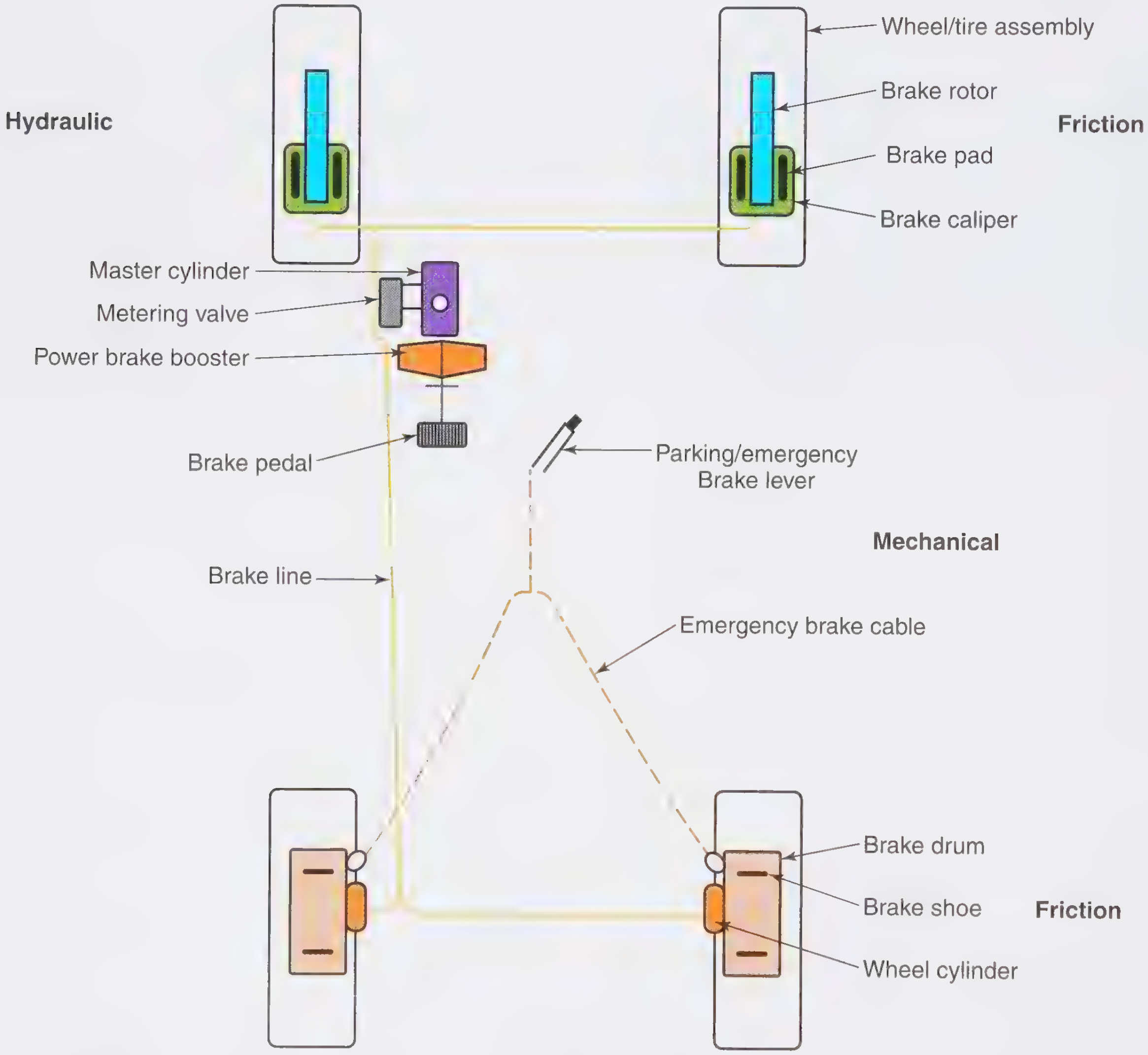

Hydraulic
Wheel/tire assembly
Brake rotor
Friction
Brake pad
Brake caliper
Master cylinder
Metering valve
Power brake booster
Brake pedal
Parking/emergency Brake lever
Mechanical
Brake line
Emergency brake cable
Brake drum
Brake shoe
Friction
Wheel cylinder

Figure 20-1. *The brake system consists of hydraulic, friction, and mechanical components.*

The hydraulic portion of the brake system operates when the driver pushes down on the brake pedal. Pedal pressure causes the master cylinder to push brake fluid through the brake lines. The hydraulic components cause the friction components to operate. In disc brakes, brake fluid pressure causes the brake caliper to push the brake pads against the rotor. In drum brakes, brake fluid pressure causes the wheel cylinder to push the brake shoes against the brake drum. The friction of the brake pads or shoes against the rotor or drum causes the wheel to stop rotating.

The hydraulic portion of the brake system operates by ***Pascal's law***, which states that the pressure in a closed liquid system is uniform. See **Figure 20-2**. If 30 pounds per square inch (psi) of pressure is applied at point *A*, then 30 psi is also applied at points *B* and *C*. The pressure is the same throughout the liquid system. This is true because a liquid cannot be compressed. If force is applied at one end of a closed system, the force is equally spread through the entire system. A gas, however, can be compressed. If there is air in the brake line, the air will be compressed and the breaking force will not be evenly distributed. This is why a brake system will not function if there is air in the system. The force from the brake pedal and master cylinder is not transferred to the wheel cylinders or calipers.

To properly function, the brake system must be closed. In a closed liquid system, absolutely nothing can enter the system, not even air. In a brake system, the liquid is brake fluid.

The mechanical portion of the brake system is also known as the parking or emergency brake. The mechanical portion of the brake system uses cables, not hydraulic brake fluid, to operate the rear brakes. A hand lever is pulled to tighten the cables to engage the rear brakes.

Friction opposes the relative movement of two surfaces in contact. When a moving surface touches a stationary surface, friction slows down and eventually stops the moving surface. If an engine is shut down on a moving vehicle, so the engine no longer powers the vehicle, the friction between the tires (moving surface) and the roadway (stationary surface) will eventually slow and stop the vehicle, even if the brakes are not applied. The friction portion of the brake system uses the motion opposition action of friction to slow and stop the vehicle. The hydraulic portion of the brake system conveys the driver's action on the brake pedal to the brake mechanisms at each wheel. In a drum brake, the brake shoes are pressed against the inside of the brake drum. In a disc brake, the brake pads are pushed against the brake rotor. The drum and rotor are the moving surfaces; the shoes and pads are the stationary surfaces. The friction between the shoes and drum or the pads and rotor slows or stops the vehicle. Friction produces heat. This heat must be dissipated because the brakes will not function properly if they become too hot. One advantage of disc brakes is that being in the open, they run cooler than drum brakes.

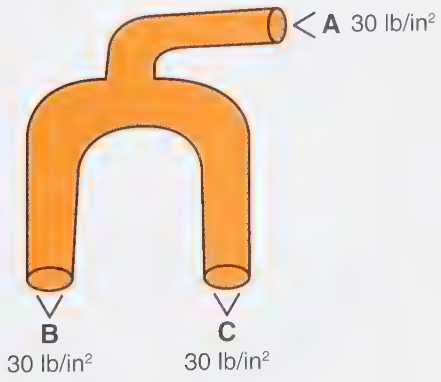


Figure 20-2. *This diagram illustrates how, in a closed system, liquid pressure is equally distributed (Pascal's law).*

Brake System Parts

The brake system parts are broken down into two groups: hydraulic components and friction components. The hydraulic components are the brake fluid, master cylinder, brake line, brake hose, valves, calipers, and wheel cylinders (as well as certain ABS components). The friction components are the drums, discs, shoes, and pads. This section explains individual parts of the brake system.

NOTE

Mechanical components consist of the lever and cables used to lock the rear brakes.

Brake Fluid

The hydraulic portion of the brake system uses brake fluid—a liquid—to operate the wheel cylinders or calipers. As mentioned previously, brakes stop the vehicle with friction, and friction produces heat. This heat causes a rise in the temperature of the brake components, including the brake fluid. Heating a liquid above its boiling point causes the liquid to become a gas. For example, heating water to 212°F (100°C) converts the water (liquid) into steam (a gas). Therefore, brake fluid must have a boiling point that is high enough that it will not change into a gas when heated during braking. The gas produced by boiled brake fluid can be compressed, and therefore, the brakes will not work properly.

What causes the brake fluid to boil? When water is added to brake fluid, it lowers the boiling point of the brake fluid to a temperature achieved during braking. How can water get into the brake fluid? Brake fluid is ***hygroscopic***, which means it readily absorbs water, such as water vapor in the air. Brake fluid contaminated with water is dangerous. Keep water out by always keeping the master cylinder closed tight. The lid should only be opened as long as necessary. Also, keep the lid closed on any container of brake fluid. It is best to open a new container of brake fluid, add it to the system, and then dispose of any remaining fluid. This will prevent the possibility of adding contaminated fluid to the system.

Brake fluids are classified by a Department of Transportation (DOT) number. The numbers are DOT 3, 4, and 5. The numbers 3 and 4 are glycol-based fluids, while 5 is silicon-based fluid. Glycol and silicone fluids should not be mixed. The vehicle's manufacturer will recommend which type of brake fluid to use.

Master Cylinder

The master cylinder converts mechanical pressure from the brake pedal into hydraulic pressure and distributes it throughout the brake system. **Figure 20-3** shows a master cylinder. When the driver pushes on the brake pedal, the linkage moves the pistons in the master cylinder. These pistons push on the brake fluid, transferring the hydraulic pressure to the wheel cylinders or calipers. As long as the brake pedal is held down, the brakes remain applied. How hard the pedal is pushed determines how much pressure is applied to the brake system. Slight pushing on the brake pedal causes a slight movement of brake system components. Pushing hard causes the maximum operation. When the brake pedal is released, the master cylinder pistons retract and the brakes release.

A master cylinder has a brake fluid reservoir, which may be directly attached to the master cylinder or it may be separate. The reservoir holds brake fluid. The reservoir is divided into two sections, each supplying fluid to half the brake system. If a leak develops in a brake line controlled by one reservoir section, the other section will still provide fluid to operate the other half of the brake system.

The brake system on most vehicles includes a power-assist unit. A vehicle equipped with a power-assist unit is said to have ***power brakes***. The power-assist unit boosts the force from the brake pedal to the master cylinder, multiplying the force applied by the driver to the pedal. The power-assist unit is bolted to the firewall and the master cylinder is bolted to the unit.

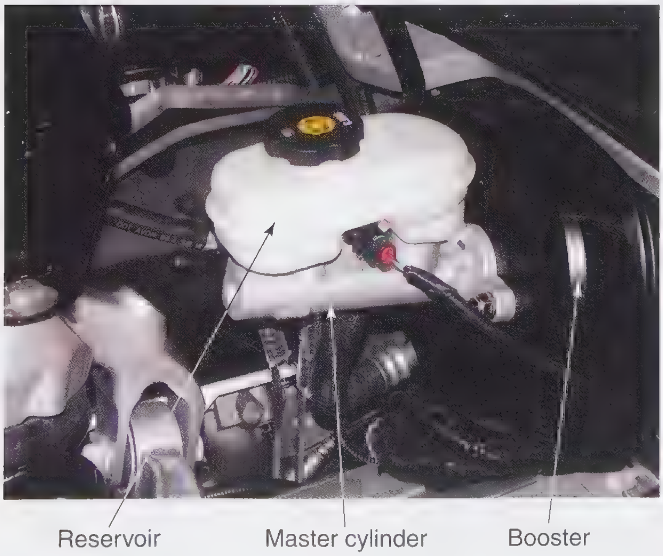


Figure 20-3. *This master cylinder is mounted on the power brake booster, which is mounted on the cowl.*

Brake Lines and Hoses

Brake lines and hoses transfer the brake fluid pressure between the master cylinder and wheel cylinders and calipers. A brake line is a double-walled steel tube. The brake line has bends that allow it to be routed from the master cylinder to the calipers and wheel cylinders. The brake line is attached to the body or frame with clips to prevent vibration. Vibration from driving could cause the brake line to rupture. The ends of the brake line are flared to form leakproof joints. A ***tubing flare tool*** is used to form these leakproof joints. The two types of flares used for brake lines are the double lap and ISO flare. See **Figure 20-4**.

A brake hose is used to make a flexible connection between the brake line and the wheel cylinder or caliper. See **Figure 20-5**. The hose can move up and down with the suspension or move in and out as the wheels are turned.

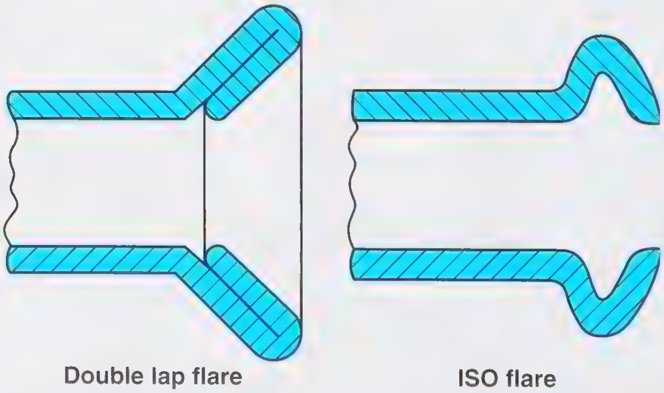


Figure 20-4. *These are double lap and ISO flares.*

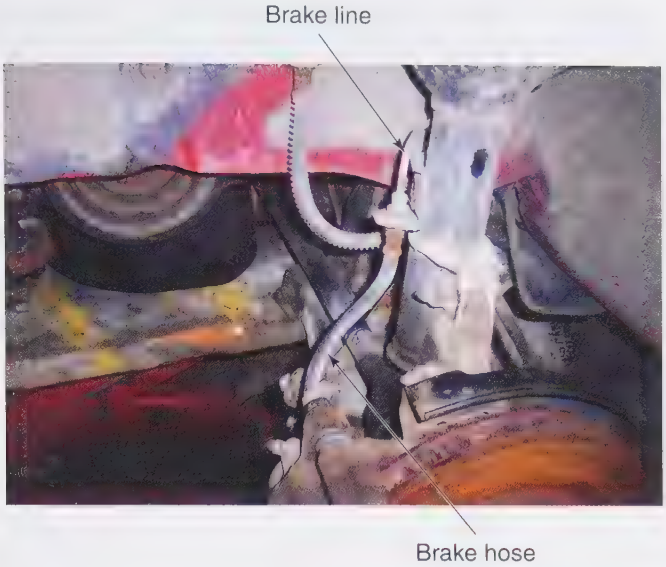


Figure 20-5. *The brake hose forms a flexible connection between the front wheels and the brake lines.*

Drum Brakes

The internal components of a drum brake are shown in **Figure 20-6**. The brake drum fits over all the components shown in the illustration. Pressure in the brake line causes the wheel cylinder to push the brake shoes against the drum. Friction created as the brake shoes are forced against the drum causes the vehicle to slow down or stop. (Return springs pull the shoes away from the drum when the brake pedal is released.) The surface of a brake shoe, called the *lining*, can be made of nonmetallic or semimetallic materials. Nonmetallic linings do not produce as much braking power as semimetallic linings. However, nonmetallic linings are quieter and do not cause as much wear on the brake drum as semimetallic linings.

There are two shoes on a drum brake: primary and secondary. The primary shoe is toward the front of the vehicle when looking at the drum brake. It may be smaller than the secondary shoe. The secondary shoe may be larger because it does more of the braking.

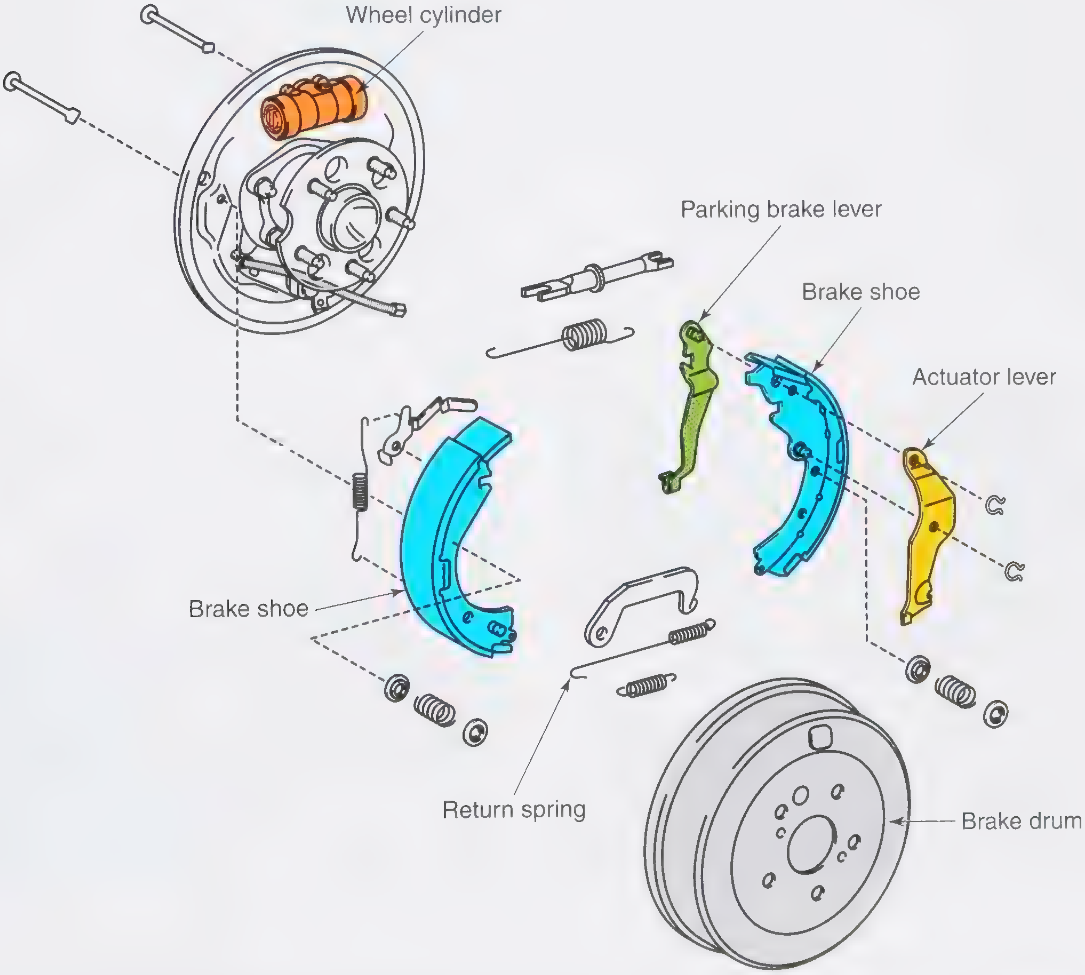


Figure 20-6. *Drum brakes consist of a backing plate, brake shoes, wheel cylinder, springs and self adjusters. (Toyota)*

As the brakes are used, the lining is gradually worn away. To keep the brake shoes in the proper location for the best braking, a self-adjuster mechanism moves the brake shoes apart as they wear. The adjustment takes place as the brakes are applied when the vehicle is driven in reverse.

Another part of drum brakes is the backing plate. The backing plate is usually bolted to the rear axle housing. It seals the inside of the drum, preventing contamination. Drum brakes may be damaged in a side impact. However, the wheel protects the drum brakes and damage is not common.

Disc Brakes

Disc brake components are shown in **Figure 20-7**. Brake fluid pressure at the caliper causes the brake pads to contact the rotor. The friction created as the pads are forced against the rotor causes the vehicle to slow down or stop. As with brake shoes, the friction material used on brake pads may be nonmetallic or semimetallic. Rotors can be ruined by overheating and must be replaced. A blue tint is a sign of heat damage.

Disc brakes may be found on the front or rear of the vehicle. If a vehicle is equipped with disc brakes at the front and the rear, it is said to have *four-wheel disc brakes*. Disc brakes may be damaged in a collision that impacts a wheel. However, disc brakes are protected by the wheel, so damage is not common.

WORKING SMART

Most newer cars have thin rotors that warp easily. Brake rotors warp because of overheating or incorrect tightening of the wheel. When putting a brake system back together, make sure to torque the lug nuts to the proper torque specifications.

Valves

Most brake hydraulic systems with disc brakes in the front and drum brakes in the rear use a combination valve. See **Figure 20-8.** The combination valve usually contains a proportioning valve, a pressure-differential valve, and a metering valve.

Brake fluid pressure is equally distributed throughout the brake system. This equal pressure distribution may not be desirable. For example, when a vehicle is traveling forward and the brakes are fully applied, much of the weight of the vehicle is transferred to the front wheels. If there is less weight on the rear wheels with the brake pressure being equal at all wheels, the rear wheels may lock up, possibly causing the driver to lose control of the vehicle. In order to prevent rear-wheel lockup during a sudden stop, a ***proportioning valve*** is used to limit the pressure to the rear brakes. A proportioning valve may be found in the brake line system at the master cylinder.

A load-sensing proportioning valve is found on some trucks and vans. These valves detect the amount of weight in the cargo area and regulate pressure to the

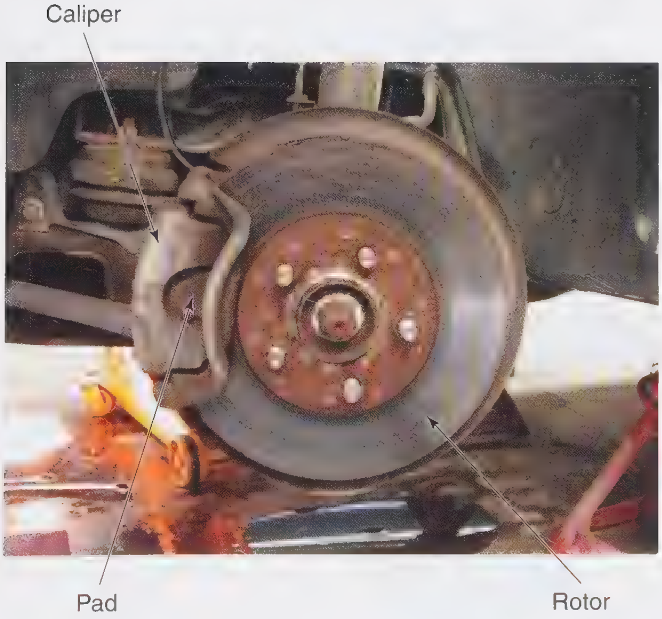


Figure 20-7. *These are the parts of a disc brake: rotor, caliper, pads.*

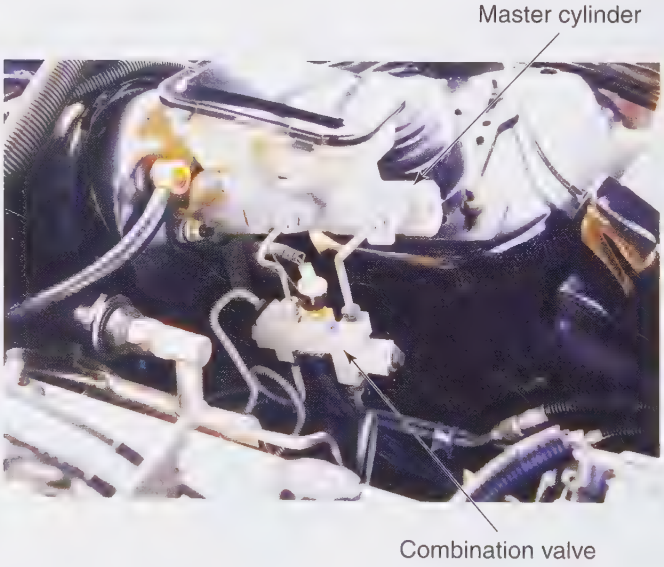


Figure 20-8. *The combination valve regulates brake fluid pressure between the front and rear brakes.*

rear brakes accordingly. When a truck is heavily loaded, more fluid pressure is applied at the rear brakes than when it is not loaded.

A ***pressure-differential valve*** senses low brake fluid pressure. If brake fluid is lost, causing a drop in brake fluid pressure, a piston inside of the combination valve will move. The pressure-differential valve senses the movement of the piston and sends a signal to illuminate the brake warning light on the dashboard. For example, if a brake line leaks due to a rust hole, the brake system is no longer closed. If the brakes are applied, the brake fluid will be forced out of the hole. There will not be enough pressure to operate the brakes. A warning light on the dashboard alerts the driver that the brake fluid pressure is low.

The ***metering valve*** limits hydraulic pressure to the front brakes until a predetermined front input pressure is reached. This pressure approximates the pressure required to overcome the retracting force of the rear brake or shoe springs.

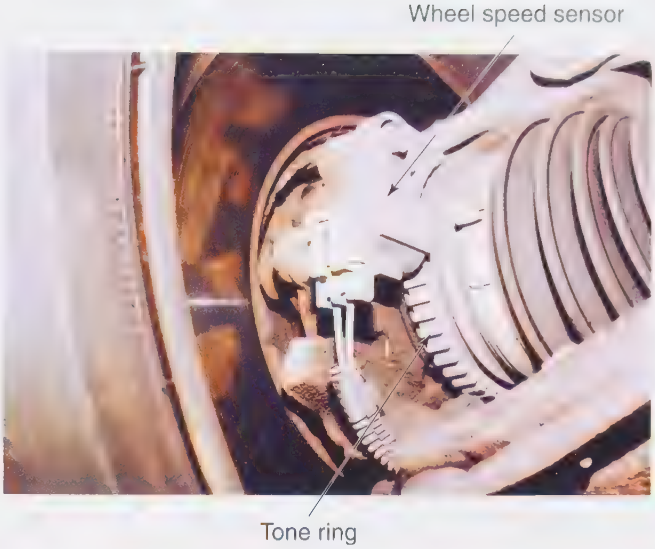


Figure 20-9. *The tone ring turns at the same speed as the wheel.*

Anti-Lock Brake System

Wheel lockup occurs when the brakes are applied so hard that the wheels stop turning before the vehicle stops moving. Locked wheels may cause a vehicle to skid out of control. An anti-lock brake system monitors wheel speed and regulates brake fluid pressure to prevent wheel lockup. A vehicle with locked wheels is not only difficult to control; but the braking action of a locked wheel is not as good at stopping the vehicle as a turning wheel. Locked wheels slide across the pavement, relying on the friction between the road and tires to stop. If the surface is slick or wet, there is minimal friction. The maximum stable braking action (MSBA) occurs just before the wheel locks up. MSBA is the number of wheel turns per minute that allow the vehicle to stop quickest while maintaining control of the vehicle.

The ***anti-lock brake system (ABS)*** allows the driver to maintain control of the vehicle when braking on a wet or slick surface. An ABS accomplishes this by pulsating the brakes—applying and releasing the brakes up to 15 times per second. The parts of a typical anti-lock brake system are listed below:

- Tone ring—Rotates at wheel speed. See **Figure 20-9**.
- Speed sensor—Determines the rotational speed of the wheel. Generates an electrical signal based on the movement of the tone ring and sends the signal to the electronic brake control module.
- Electronic brake control module (EBCM)—Receives wheel speed information from the speed sensor(s) and sends an electrical signal to the hydraulic actuator. The EBCM is the brain of the anti-lock brake system. It continuously monitors the operation of all components of the ABS system. If a problem with a component is detected, such as low voltage from a wheel sensor, the EBCM alerts the vehicle driver by activating the ABS warning lamp on the dash. The EBCM makes a self-diagnostic check of the ABS system components each time the vehicle is started. During the self-diagnosis, the ABS warning lamp is on. If all components are functional during the self-diagnosis, the warning lamp goes out. If a problem is detected, the lamp remains on. A trouble code, indicating the location of and the type of problem, will be stored in the vehicle's onboard computer.
- Hydraulic actuator—Receives electrical signals from the EBCM and applies/releases brake fluid pressure to maintain optimum wheel speed during braking.

There are three types of anti-lock brake systems: one-channel ABS, three-channel ABS, and four-channel ABS. In a one-channel ABS, the rear wheels are controlled together. This type of system is often referred to as *rear ABS*, or *RABS*. See **Figure 20-10**. The speed sensor may be located in the transmission, differential, or transfer case. Rear ABS may be found on pickup trucks. Rear ABS prevents rear wheel lockup.

In a three-channel ABS, the front wheels are individually regulated and the rear wheels are regulated together. See **Figure 20-11**. There are speed sensors at each front wheel and there may be one or two speed sensors for the rear wheels.

In four-channel ABS, each wheel has a speed sensor, so each wheel is individually regulated. This system provides the best anti-lock braking action. See **Figure 20-12**.

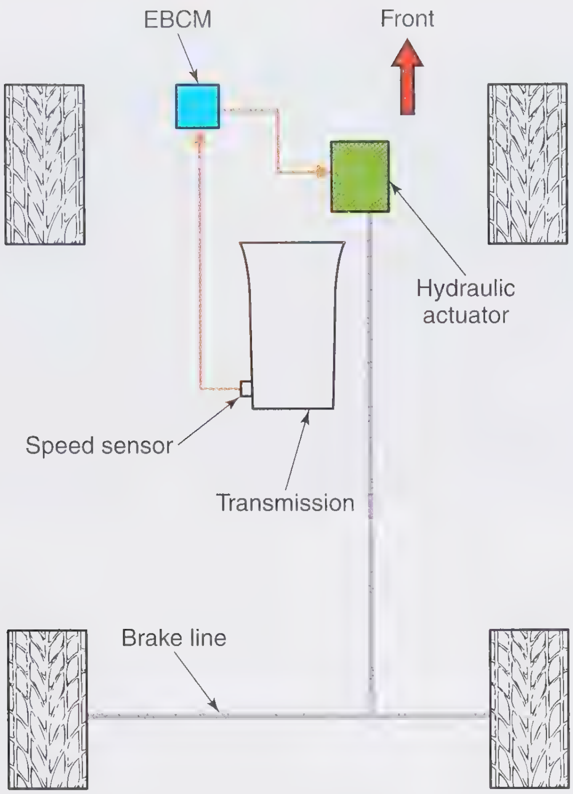

EBCM
Front
Hydraulic actuator
Speed sensor
Transmission
Brake line

Figure 20-10. *A one-channel ABS controls the rear wheels together.*

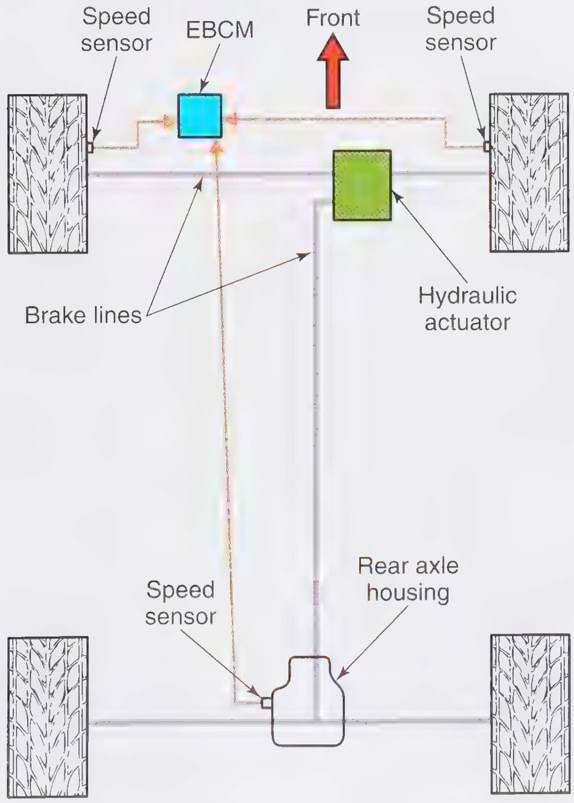

Speed sensor
EBCM
Front
Speed sensor
Brake lines
Hydraulic actuator
Speed sensor
Rear axle housing

Figure 20-11. *A three-channel ABS controls the front wheels individually and the rear wheels together.*

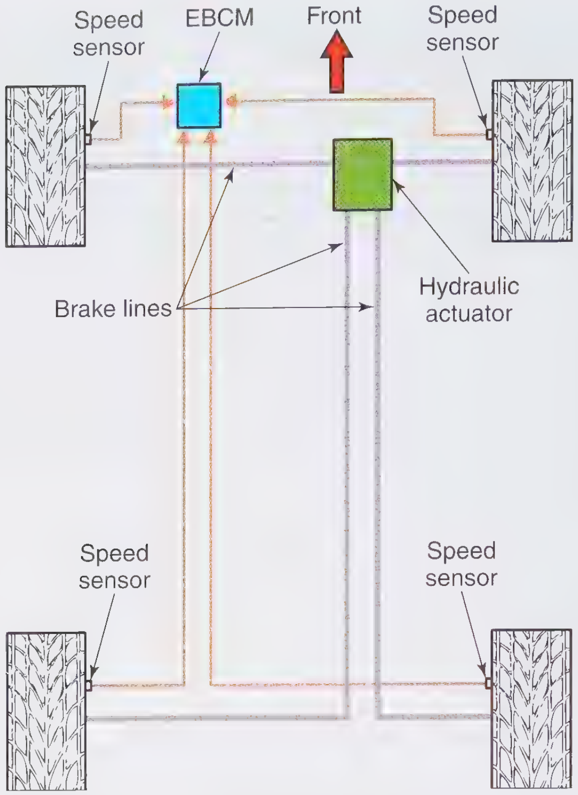

Speed sensor
EBCM
Front
Speed sensor
Brake lines
Hydraulic actuator
Speed sensor
Speed sensor

Figure 20-12. *A four-channel ABS controls all wheels individually.*

ABS components may be damaged in a collision. Some components, such as the EBCM and the hydraulic actuator, may be found in vulnerable locations. For example, a hydraulic actuator may be bolted behind the radiator support in the left-front corner of the engine compartment. A hard impact on the left-front corner of the vehicle, or even an impact above the bumper, could damage this part. An impact on a wheel may damage a tone ring or speed sensor.

Traction Control and Electronic Stability Systems

A ***traction control system (TCS)*** is part of some anti-lock brake systems. However, the TCS aids in vehicle acceleration, not braking. Wheel spin is caused by a tire losing traction. A slick surface does not provide enough friction to allow the tire to grab it. Wet or icy pavement is an example of a slick surface. The TCS detects excessive wheel spin, controls engine torque, and applies the brakes to regain traction.

Electronic stability control systems use high-tech sensors, the vehicle's central computer, and mechanical actions to enhance driver safety. ESC helps compensate for loss of traction caused by oversteer or understeer.

An ESC measures the driver's steering input against the vehicles yaw angle (side to side movement) and rear-wheel traction. If a disparity is detected, brakes are automatically applied to one or more wheels to steer the car. If necessary, the ESC commands the engine to reduce power until control is regained.

Brake System Repair

The following section highlights the service and repair procedures commonly performed by the auto body technician. Much of brake system service is diagnosing the problem and replacing damaged parts. Replacing components is not overly difficult. However, diagnosing the problem can be, unless a plan is followed. **Figure 20-13** shows a flowchart. A flowchart is a logical progression of checks to determine the cause of a problem. A technician who follows a logical path will find the diagnosis process to be much easier than a technician who indiscriminately replaces components.

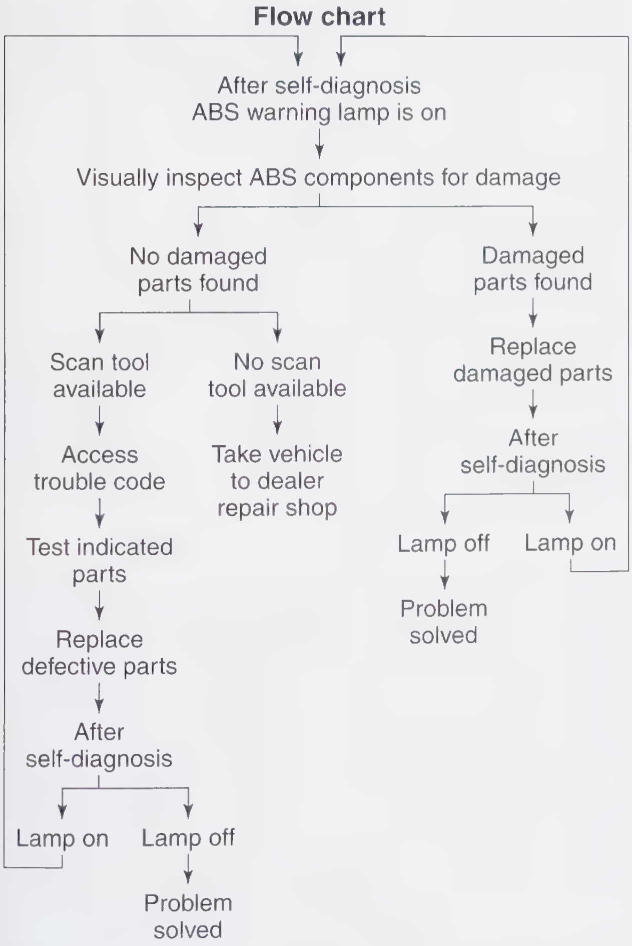

Flow chart
After self-diagnosis ABS warning lamp is on
Visually inspect ABS components for damage
No damaged parts found
Damaged parts found
Scan tool available
No scan tool available
Replace damaged parts
Access trouble code
Take vehicle to dealer repair shop
After self-diagnosis
Lamp off
Lamp on
Test indicated parts
Problem solved
Replace defective parts
After self-diagnosis
Lamp on
Lamp off
Problem solved

Figure 20-13. *This is a flowchart. Each step requires that the technician make a decision or perform a task. A flowchart is a map for the repair process.*

Servicing Worn Components

Brake system components such as brake pads, brake shoes, rotors, and drums will become worn with use. Worn out brake system components may result in a dangerous condition. A technician must be aware of these potential problems. If, during repair, the technician notices that the brake components are worn, the customer should be notified of their condition.

Figure 20-14 shows an example of how to check for brake pad wear. As a general rule of thumb, there should be at least 1/8" of friction material left on the brake pads. Some disc brakes are equipped with a wear indicator. When the friction surface has worn down to a critical level, the wear indicator touches the rotor, producing a sound.

A severely grooved rotor is shown in **Figure 20-15**. Minor scratches are not a problem. A grooved rotor can sometimes be turned and reused. A heat-damaged, cracked, or thin rotor must be replaced.

Worn brake shoes must be replaced. For riveted brake shoes, there should be at least 1/32" of friction surface above the rivets. For bonded shoes, the friction surface must be at least 1/16" thick. Also, replace a shoe that has a cracked lining. **Figure 20-16** shows a worn brake drum. Replace thin or heat-damaged drums. Grooved drums can sometimes be resurfaced on a lathe, if the grooves are not too deep.

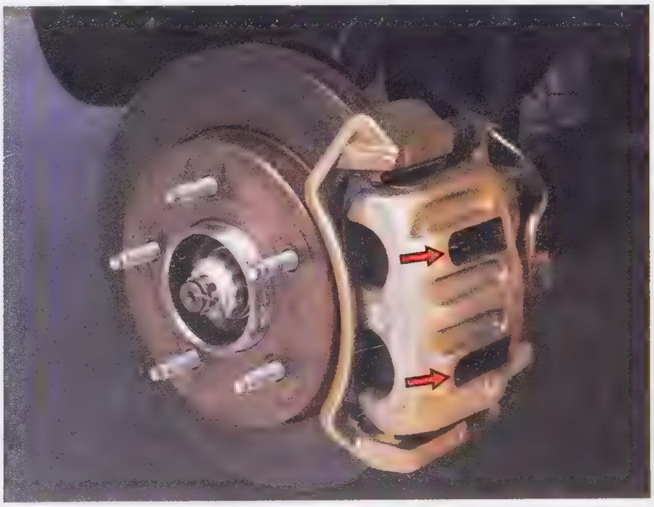


Figure 20-14. *Brake pad thickness can be checked by inspecting the areas highlighted by the arrows. In general, the pads should be thicker than a nickel.*

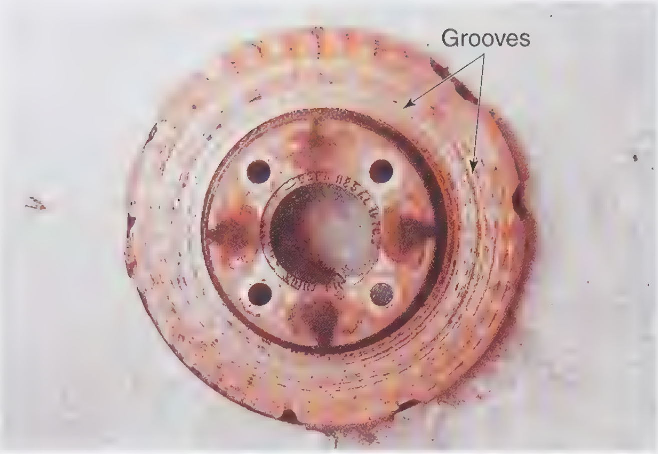


Figure 20-15. *This brake rotor is grooved.*

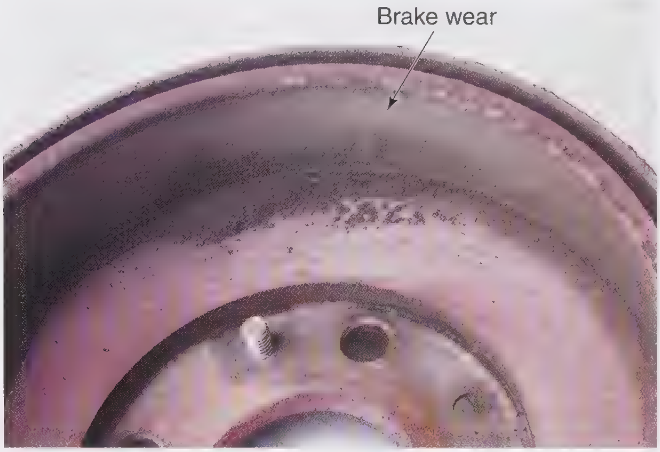


Figure 20-16. *This brake drum is worn, but not deeply scored.*

WARNING

If any leaking brake fluid is noticed, the customer should be notified. Never release a vehicle with defective brakes to a customer.

Disconnecting a Brake Line or Hose

A brake hose connects the steel brake lines to the calipers. When a drive train is removed from a front-wheel-drive vehicle, the brake hoses must be disconnected from the calipers. A line wrench (flare-nut wrench) should be used when loosening brake line fittings. See **Figure 20-17**. The line wrench surrounds and protects the fitting, and provides a good grip. After loosening the fitting, remove and cap the brake line to prevent contamination of the brake fluid. Contamination is the reason many technicians do not use penetrating oils when working on brake line fittings. Some manufacturers require that the copper washers be replaced each time the brake line is removed from the caliper. (Not all vehicles use copper washers.) Rear brakes also have hoses that connect the rigid steel brake lines to the wheel cylinder/brake drums or disc brake calipers.

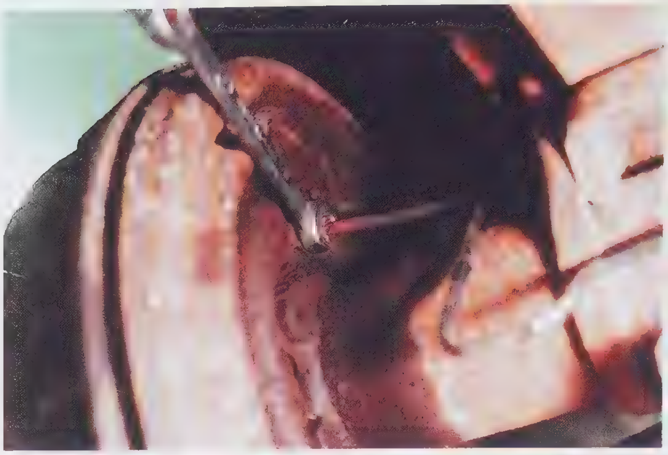


Figure 20-17. *A line wrench (flare-nut wrench) is used to disconnect a brake line from a wheel cylinder.*

Moving a Brake Line

During frame repair, clamps or chains are often used to hold the vehicle in place. A tightened clamp or chain may damage a brake line if precautions are not taken. To prevent damage, move the brake lines out of the way. To move a brake line, locate the hold-down clips. Remove the bolts holding the clips in place and carefully slip the brake line out of the way. Do not twist or kink the line!

Replacing a Brake Line

Steel brake lines can rust and leak. They can also be damaged in a collision. **Figure 20-18** shows a rusted brake line. A rusted or damaged brake line must be replaced. To begin brake line removal, locate the brake line fittings. Disconnect the fittings using a line wrench. Two wrenches may be required, one to turn the fitting nut and another to hold the connector in place. Remove the bolts securing any hold-down clips to the body or frame, and remove the brake line.

Obtain a new line. In many cases, brake line is available already bent to the proper shape. In some cases, however, pre-bent brake lines are not readily available. Straight replacement brake lines must be bent to the proper configuration. Select a replacement brake line of

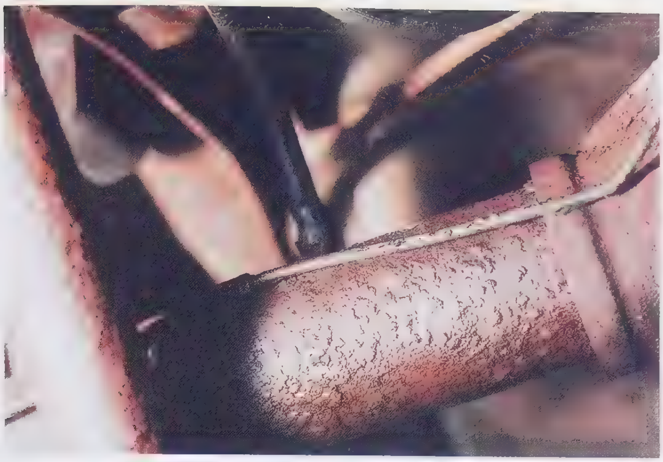


Figure 20-18. *This brake line has a rust hole. The rear axle housing is wet from leaking brake fluid.*

the proper diameter. When bending brake lines, use a tool such as the one shown in **Figure 20-19**. If you kink the brake line when bending it, you must replace the line. If the line is too long, it can be cut with a tubing cutter. Each end of the line must have a flare. The flare can be made with an ISO flare tool or a double-lap flare tool. Be sure to place the flare nuts on the line before making the flare.

Align the new brake line on the vehicle and install the fitting nuts. Then, bolt the line's hold-down clips to the frame or body. After replacing the brake line, bleed the system to remove any trapped air.

Replacing a Brake Hose

A brake hose can be cut in a collision. Also, hoses degrade with age. A brake hose should be replaced if it shows signs of damage or leakage. Brake hoses are usually secured to the vehicle with clips or bolts. Disconnect the fittings on each end of the hose and then remove the retaining clips or bolts. If washers are present at the connection to the caliper, they should be replaced. Install the new brake hose and bleed the brake system.

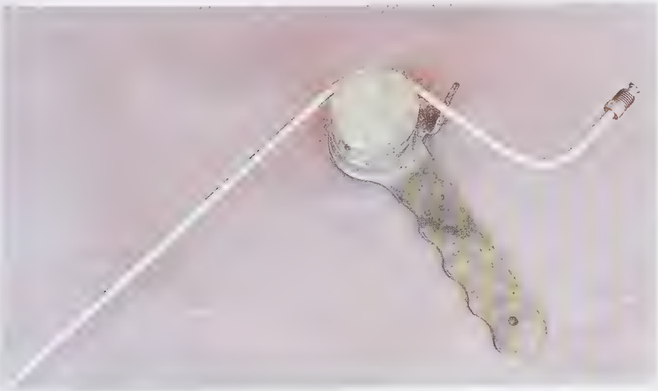


Figure 20-19. *Using a brake line bending tool prevents kinks in the lines.*

Brake Bleeding

Bleeding should be done whenever the brake hydraulic system is opened. Air in the brake lines is dangerous because air can be compressed. Brake bleeding removes air from the system. Vehicles equipped with an ABS may require a more involved bleeding process. Check the manufacturer's recommendations for the proper bleeding procedure. Before opening any lines, an ABS must be depressurized following the manufacturer's instructions.

Manual Bleeding

Manual brake bleeding requires two technicians, one to push on the brake pedal and another technician to open the ***bleeder valve*** at each wheel. On drum brakes, the bleeder valve is located on the outside of the backing plate. The bleeder valve is part of the wheel cylinder. On disc brakes, the bleeder valve is located on the caliper. Fill the master cylinder with brake fluid. Monitor the master cylinder so that it contains fluid at all times during the bleeding process. If the master cylinder empties and pulls air into the hydraulic system, you must start the bleeding procedure over.

Begin by pumping the brake pedal about ten times with all bleeder valves closed. The pedal may sink to the floor during pumping. After pumping, hold down the pedal. Attach a hose to the bleeder on the wheel furthest from the master cylinder and run the hose to a jar of clean brake fluid. Open the bleeder valve. Allow the air and fluid to escape from the valve. Then, close the valve. Pump the brake pedal again. Hold down the pedal and then open the valve. Continue this procedure until only brake fluid (and no more air) flows from the line being bled. Repeat the procedure at the other wheels, moving closer toward the master cylinder with each wheel.

Pressure Bleeding

Pressure bleeding requires special equipment, but only one technician is needed. The pressure bleeder is hooked up to the master cylinder. The technician then opens the bleeder valve at the wheel farthest from the master cylinder. The bleeder pushes brake fluid through the brake lines. The open bleeder valve allows air and brake fluid to escape. When all of the air is released, the bleeder valve is closed. This procedure is repeated at each wheel, working toward the master cylinder.

ABS/TCS Bleeding

Specific procedures may be required to bleed an ABS/TCS system. Refer to the manufacturer's repair manual. In some systems, a scan tool is required to bleed the actuator. The scan tool is used to operate the actuator, pushing air from the actuator into the brake lines. The brake lines are then bled in the conventional way.

Servicing Drum Brakes

A rear spindle or rear axle replacement may require brake drum removal. The brake drum may be held in place by screws as shown in **Figure 20-20**. Remove the screws and slide off the drum. Other brake drums may not have any fastener. If that is the case, just slide off the drum.

A side hit at the rear of a pickup truck may damage the rear axle housing. The axle housing may be replaced with a used assembly. The brakes, drum or disc, on the used assembly must be inspected. The used assembly will usually include the brake drums or rotors. Often, the brake lines on the used assembly are cut when the assembly is removed from the salvage vehicle. The stub of the brake line remains on the wheel cylinder. The brake drums must be removed and the internal components inspected. The used assembly may have laid in a junkyard for years and may be corroded. Some brake drums have holes tapped for bolts. If removal of the drum proves difficult, a 5/16" coarse threaded bolt is installed in each hole. The bolt pushes against the inside of the brake, popping the brake drum loose. Another style of brake drum uses a nut on a spindle to hold the drum in place. The nut is under a grease cap.

If the brake components on the damaged rear axle assembly are not damaged and do not have excessive wear, transfer all the brake components from the damaged rear axle to the replacement rear axle assembly. Replace leaking wheel cylinders, broken springs, worn brake shoes, or scored brake drums. If new shoes are required, replace both left and right sides.

Both the brake shoes and the brake drum are subject to wear. As the brakes are used, a small amount of the shoe lining and drum are worn off. Worn brake drums may be scored, as shown in **Figure 20-21**. A scored brake drum can be turned on a brake lathe to cut a smooth surface. Turning is only possible if the drum thickness will remain greater than the minimum. The minimum thickness of a brake drum is stamped on the drum. A badly scored drum may need so much cutting that it will be thinner than minimum thickness after turning. If the drum is too thin, it will not be able to absorb the heat produced by braking.

Disassemble only one brake at a time. This will leave an assembled brake as a reference when putting the other brake back together. The brake shoes are held in place on the backing plate with pins and spring washers. Brake springs pull the shoes back into place after foot pressure is removed. Remove the springs and the spring washers. Pull the brake shoes from the emergency brake cable and wheel cylinder. Check the wheel cylinder for leaks. A leaking wheel cylinder must be replaced. Turn the self-adjuster to the minimum value. Install the new shoes in the wheel cylinder tabs and reconnect the emergency brake cable. Mount the shoes on the backing plate with pins and spring washers. Position the brake springs. Measure the brake drum thickness to determine if it can be reused. If the drum is grooved, have the drum machined, or replace the drum.

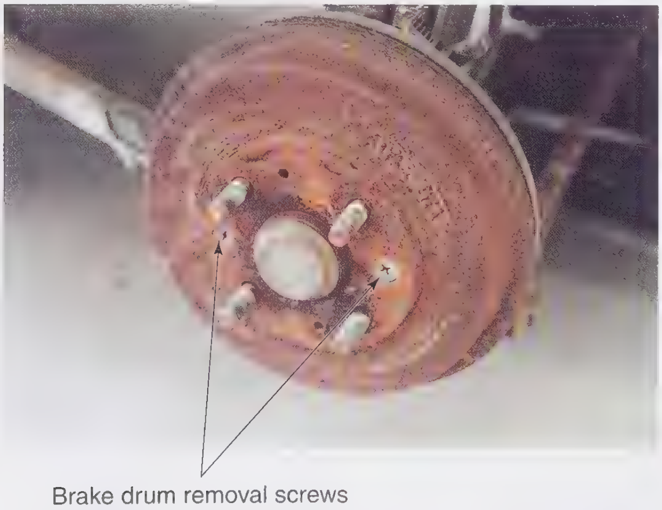


Figure 20-20. *This brake drum is held in place with screws.*

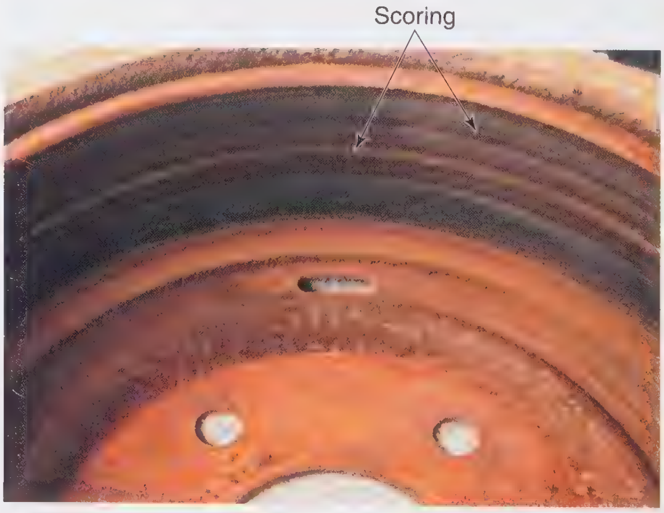


Figure 20-21. *This brake drum is scored. Notice the deep groove in the middle.*

Position the drum in place over the brakes. Install any fasteners. When both brakes are assembled, the brakes can be adjusted by backing up the vehicle and applying the brakes.

CAUTION

When the brake drum is off, do not step on the brake pedal. This will ruin the wheel cylinder.

Servicing Disc Brakes

Both the pads and the rotor are subject to wear. Like brake shoes, brake pads should be replaced when the pad is worn to the minimum thickness. A scored rotor, **Figure 20-22**, can be turned on a lathe to a smooth surface as long as the minimum thickness is retained. A front hit on a wheel may bend the front suspension. The damaged suspension may be replaced with a used assembly or new parts. The used assembly may include the brake rotor and caliper. As with drum brakes, transfer undamaged and usable brake parts from the damaged suspension to the replacement parts. If the original brake parts, such as the rotor, pads or caliper, are worn, damaged or broken they must be replaced. If the front pads are replaced on one side of the vehicle, also replace pads on the other side.

Steering knuckle replacement requires brake caliper and rotor removal. To remove a caliper and rotor, first check the service manual for the proper procedure. Calipers are usually secured with bolts or bushings. Remove the bolts or bushings. Do not hang the caliper by the brake hose. Instead, hang the caliper by a piece of wire as shown in **Figure 20-23**. Also, do not step on the brake pedal when the caliper is removed.

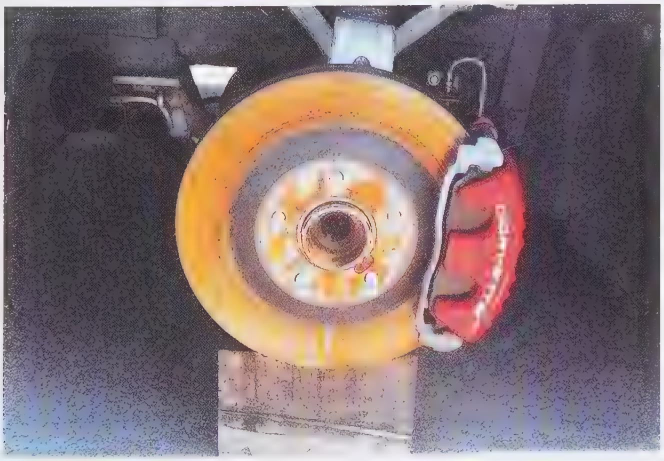


Figure 20-22. *This rotor is scored.*

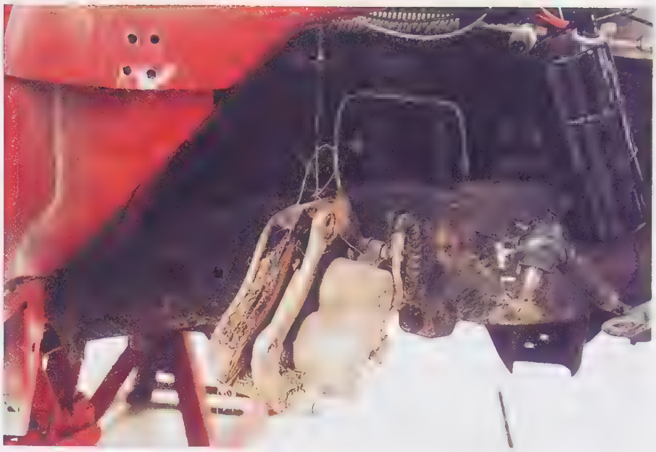


Figure 20-23. *After removing a caliper, suspend it from a wire rather than by the brake hose. In this example, the right front suspension has been removed.*

Rotor removal may be as simple as pulling the rotor off the hub. On some vehicles, the rotor is retained with screws or a nut. Reverse the removal order to reinstall the caliper and rotor. The caliper must be removed if the brake pads are being replaced. Remove about one-half of the brake fluid from the master cylinder with a syringe. Unbolt the caliper from the steering knuckle. Remove the old pads and any shims. Before installing new pads, the piston in the caliper must be pushed in until it is level with the body of the caliper. The piston can be forced in with a C-clamp. If the vehicle has anti-lock brakes, open the caliper bleeder valve while moving the piston by tightening the C-clamp. Close the bleeder valve once the piston is no longer extended from the caliper. Do not push the piston into the caliper. This would damage the seal. Install the pads and any shims. Measure the thickness of the rotor. Machine or replace the rotor as needed. Install the caliper around the rotor and on the steering knuckle. Tighten the caliper fasteners to the specified torque value.

Inspecting ABS Components

An ABS lamp that remains lit after the vehicle has been started indicates a system problem. To inspect the system, start from the impact area and work outward. Some examples of damage are:

- Chipped or cracked tooth on the tone ring.
- Broken wire on the speed sensor.
- Cracked speed sensor housing.
- Bad ground on the EBCM.
- Damaged actuator.

Replace any damaged components.

The following conditions, in addition to collision damage, may cause an ABS lamp to indicate a problem: debris on the tone ring, loose wire on the speed sensor, or improperly sized tires.

A trouble code will be stored in the on-board diagnostic computer if the ABS warning lamp is lit. A scan tool is plugged into the on-board diagnostic computer port to access the trouble code. The trouble code displayed on the scan tool will identify and locate the problem. For example, a trouble code may indicate that there is no signal from the right front wheel speed sensor. With the vehicle mounted on a lift, disconnect the speed sensor on the right front wheel. The probes from an AC voltmeter can be attached to the terminals on the speed sensor. Spinning the wheel by hand should produce at least 100 mV at the speed sensor terminals. If the speed sensor cannot produce the minimum voltage, replace the speed sensor. If the speed sensor does produce the minimum voltage, check the wiring in between the connector and the EBCM.

If the wheel speed sensor must be replaced, the distance between the wheel speed sensor tip and the tone ring, called the air gap, may have to be set. The new wheel speed sensor tip may have a paper covering that is used to set the air gap. The new sensor is installed so that the paper covering just touches the tone ring. The covering is then slipped off, and the air gap is correct.

In most body shops, if a visual inspection of the ABS system does not turn up any obvious damage, a vehicle with an illuminated ABS lamp is taken to the vehicle dealer repair shop. The repair shop can diagnose the problem with a scan tool. Due to the high cost and need for yearly updates, a scan tool is not commonly owned by a body shop.

Summary

- Hydraulic brakes operate by fluid pressure in a closed system.
- To properly function, the brake system must be closed. In a closed liquid system, absolutely nothing can enter the system, not even air.
- Air in the brake system is dangerous because it decreases or even eliminates the braking action.
- Friction between the brake shoes and the drum, or the pads and the rotor slows down and stops the vehicle.
- Brake system parts are broken down into two groups: hydraulic components and friction components.
- Many brake components are subject to wear. Worn out brake system components result in a dangerous condition.
- Brake fluid is contaminated by water.
- The ends of a brake line are flared to form a leakproof joint.
- Customers should be informed when worn brake components are discovered.
- Wheel lockup occurs when the brakes are applied so hard that the wheels stop turning before the vehicle stops moving. Locked wheels may cause a vehicle to skid out of control.
- ABS helps maintain control of the vehicle when stopping on a slick surface.
- There are three types of anti-lock brake systems: one-channel ABS, three-channel ABS, and four-channel ABS.
- Bleeding should be done whenever the brake hydraulic system is opened. Air in the brake lines is dangerous because air can be compressed. Brake bleeding removes air from the system.

Review Questions

Please do not write in this textbook. Place your answer on a separate sheet of paper.

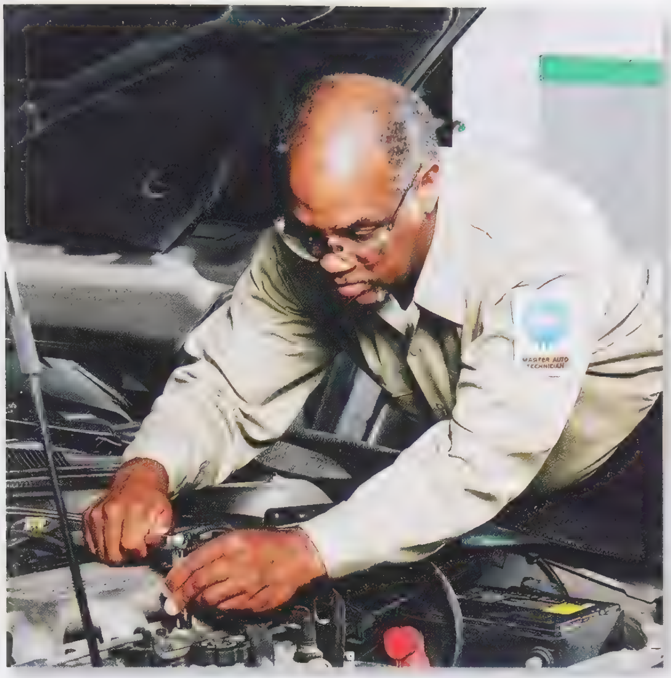
1. Explain Pascal's law.
2. List and give the function of three parts of a drum brake system.
3. Brake fluid is described as ______ because it readily absorbs water.
4. A brake rotor is subject to wear. True or False?
5. The friction of the brake pads against the brake rotor produces ______.
6. A gas can be compressed, but a liquid cannot be compressed. True or False?
7. List and give the function of three parts of a disc brake system.
8. An ABS helps a vehicle stop in a shorter distance on dry pavement. True or False?
9. Explain what an ABS does.
10. A vehicle is moving. The brakes are fully applied and the wheels no longer turn. The wheels are ______.
11. What does minimum thickness of a brake rotor mean?
12. A(n) ______ valve limits brake fluid pressure to the rear brakes.
13. Water contamination of brake fluid raises the boiling point of the brake fluid. True or False?
14. Explain the function of a speed sensor.
15. The ABS lamp is on at all times. The brake system may still be functioning. True or False?
16. List and explain the three types of ABS.
17. A traction control system is the same as a four-wheel drive. True or False?

18. The parking brake system is not hydraulic. It is ______.
19. Removing trapped air from the brake system is called ______ the brakes.
20. A caliper, brake pad, and rotor are parts of a ______ brake system.

ASE-Type Questions

1. A brake line needs to be replaced. The only replacement line available is slightly smaller in diameter than the original line. Technician A does not want to use the smaller line. Technician B says that the smaller line will make more brake pressure, allowing the brakes to work better. Who is right?
   (A) A only.
   (B) B only.
   (C) Both A and B.
   (D) Neither A nor B.
2. All of the following are parts of a drum brake system EXCEPT:
   (A) brake pad.
   (B) brake drum.
   (C) brake shoe.
   (D) brake spring.
3. Which of the following is not subject to wear?
   (A) Brake shoe.
   (B) Brake pad.
   (C) Backing plate.
   (D) Brake drum.
4. The brake shoes are worn to the thickness of a dime. Technician A thinks that the shoes are all right. Technician B thinks that the shoes are too worn to be used. Who is right?
   (A) A only.
   (B) B only.
   (C) Both A and B.
   (D) Neither A nor B.
5. A brake rotor has a blue color. This means that the rotor is ______.
   (A) all right to use
   (B) heavy duty
   (C) not reuseable
   (D) cracked
6. An ABS lamp stays lit at all times. Technician A thinks that the ABS is functional. Technician B thinks that a lit ABS lamp warns that the brake fluid level is low. Who is right?
   (A) A only.
   (B) B only.
   (C) Both A and B.
   (D) Neither A nor B.
7. A brake drum has deep grooves. Technician A says that the minimum thickness is stamped on the outside of the drum. Technician B wants to reuse the drum as is because the new brake shoes will wear into the grooves. Who is right?
   (A) A only.
   (B) B only.
   (C) Both A and B.
   (D) Neither A nor B.
8. The brake system will be manually bled. Technician A says that two technicians are required. Technician B says that only one technician is required. Who is right?
   (A) A only.
   (B) B only.
   (C) Both A and B.
   (D) Neither A nor B.
9. A brake pedal sinks to the floor when the brakes are applied. Which of the following is the most likely cause?
   (A) Hole in the brake line.
   (B) Kinked brake hose.
   (C) Kinked brake line.
   (D) Stuck caliper.
10. An OEM replacement brake line is not available. Technician A wants to bend the replacement brake line by hand. Technician B thinks that only OEM brake lines can be used. Who is right?
    (A) A only.
    (B) B only.
    (C) Both A and B.
    (D) Neither A nor B.
11. A brake drum is stuck and cannot be removed. Technician A wants to heat the drum with a torch. Technician B wants to install a 5/16" coarse threaded bolts into holes in the drum to pop the brake drum loose. Who is right?
    (A) A only.
    (B) B only.
    (C) Both A and B.
    (D) Neither A nor B.
12. A caliper needs to be moved to replace a rotor. Technician A wants to hang the caliper from the spring by the brake hose. Technician B wants to hang the caliper from the spring by a piece of wire. Who is right?
    (A) A only.
    (B) B only.
    (C) Both A and B.
    (D) Neither A nor B.

13. A brake drum is removed to check the shoes. Technician A wants to step on the brake pedal to check the operation of the wheel cylinder. Technician B says that the wrong brake shoes were installed on the vehicle because one is bigger than the other. Who is right?
    (A) A only.
    (B) B only.
    (C) Both A and B.
    (D) Neither A nor B.
14. Which of the following is a type of flare on a brake line?
    (A) ISD.
    (B) IST.
    (C) ISO.
    (D) ISP.
15. A container of brake fluid has been left open for three days. Technician A says it is okay to use because it is clear. Technician B says the brake fluid is contaminated and should not be used. Who is right?
    (A) A only.
    (B) B only.
    (C) Both A and B.
    (D) Neither A nor B.



Chapter 21

Cooling, Heating, and Air Conditioning Systems

Objectives

After studying this chapter, you will be able to:

- List the parts of the cooling, heating, and air conditioning systems.
- Explain the function of cooling, heating, and air conditioning system parts.
- Explain how the cooling, heating, and air conditioning systems work.
- Identify damage or wear on cooling, heating, and air conditioning system parts.
- Replace various cooling, heating, and air conditioning system parts.

Technical Terms

accumulator
air conditioning system
ambient temperatures
compressor
condense
condenser
coolant
cooling system
desiccant
electronic leak detector
evacuation
evaporate
evaporator
fan
fan clutch
flow restrictor
heating system
hose clamps
hydrometer
overheat
ozone layer
pressurized
radiator
radiator cap
radiator hoses
receiver/drier
refrigerant identifier
refrigerant lines
Schrader valves
service fittings
thermostat
water pump

Introduction

This chapter explains the components and functions of the heating, cooling, and air conditioning systems. Many of these systems are located in the front of the engine compartment and are subject to damage during collisions. The replacement of commonly damaged and worn-out components is covered.

Cooling System

An engine produces heat as it runs. This heat, if uncontrolled, will damage the engine. The ***cooling system*** manages the heat produced by the engine. When a cold engine is started, the cooling system helps the engine warm up quickly. When the operating engine temperature is reached, the cooling system maintains that set temperature. The cooling system must maintain proper engine temperature in a variety of ***ambient temperatures*** (surrounding air temperature) and engine loads. Ambient temperatures may vary from below 0°F (-17.7°C) to more than 100°F (37.7°C). Engine load depends on how much weight the vehicle is carrying, as well as the incline of the road. When the engine is running the cooling system is ***pressurized***. In other words, there is more pressure inside the system than outside the system. ***Coolant*** is circulated through the cooling system to absorb heat from the engine block. The coolant passes through a radiator, where the coolant loses heat to the air passing over the radiator fins. Thus, the coolant is constantly gaining and losing heat.

Cooling system failure is usually caused by a loss of coolant or obstruction of coolant flow. If the engine is operated with a faulty cooling system, the engine will ***overheat*** (engine temperature over normal operating temperature). Engine overheating can cause damage to the cylinder heads and head gaskets. It also leads to premature breakdown of oil, which can lead to damaged pistons and bearings. Proper cooling system function is essential for long engine life.

Cooling System Parts

A typical cooling system is shown in **Figure 21-1**. The combustion of gases in the engine block and cylinder head produces heat. Coolant flows through passages in the engine block and cylinder head to absorb and remove this heat. To properly function, the coolant passages must be unrestricted.

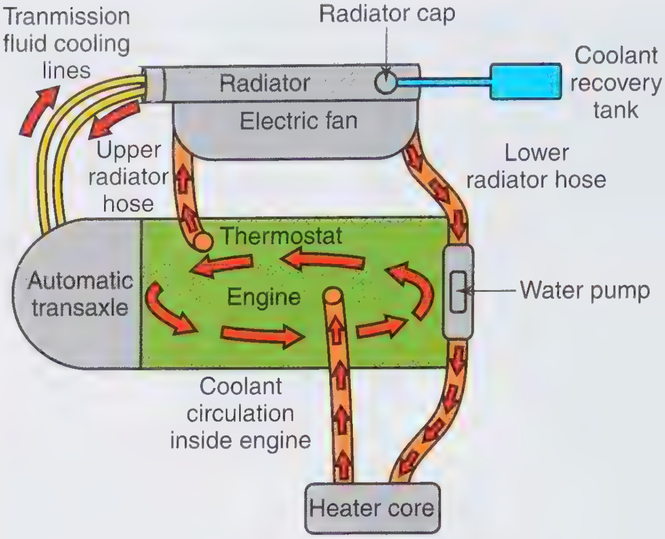


Figure 21-1. *The parts of a typical cooling system include the radiator, radiator cap, coolant recovery tank, water pump, radiator hoses, thermostat, and fan.*

Heated coolant flows to the ***radiator***. The radiator consists of a series of finned tubes. See **Figure 21-2**. The heat from the coolant flows to the fins. As air passes over the fins, the heat is absorbed by the air. The coolant, now at a lower temperature because of heat removal, flows back to the engine. The radiator has two coolant hose connections, one to bring hot coolant from the engine to the radiator and the other to move the cooled coolant from the radiator back to the engine. The coolant flow through a radiator can be either from side to side or from top to bottom.

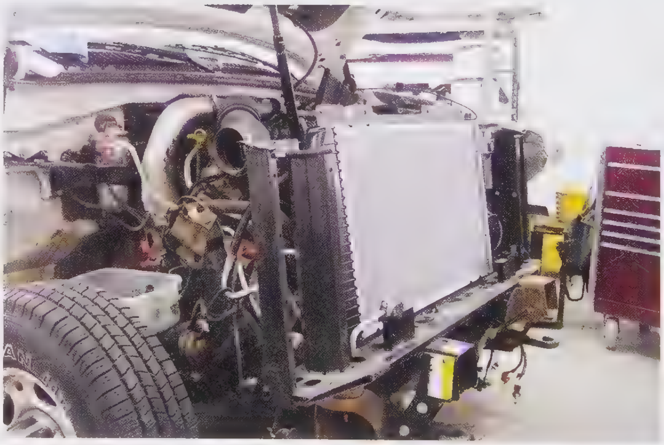


Figure 21-2. *A radiator is made out of aluminum or brass and is held in place by the radiator support. Aluminum is the material of choice for late-model vehicles.*

All cooling systems have a ***radiator cap***. The radiator cap seals the cooling system and allows pressure to build within the system (to about 14 to 16 psi) when the engine is at operating temperature. The radiator cap also prevents an over-pressure condition within the system.

Vehicles equipped with an automatic transmission have transmission fluid lines attached to the radiator. These lines bring transmission fluid to the radiator, where it is cooled and returned to the transmission.

A coolant recovery tank is shown in **Figure 21-3**. This tank accepts coolant from the radiator through a hose. As the engine warms up and pressurizes the cooling system, some coolant is pushed from the radiator into the coolant recovery tank.

The heat of combustion during engine operation slightly expands the coolant, creating pressure. If enough pressure is produced, a valve in the radiator cap opens and allows coolant to travel to the coolant recovery tank. When the engine is shut off and cools, the coolant contracts, creating a slight vacuum in the cooling system. The excess coolant that was pushed into the coolant recovery tank is pulled back into the radiator.

On some vehicles, the coolant recovery tank and hose are pressurized. In these systems, the radiator cap is on the coolant recovery tank.

The ***water pump*** is the heart of the cooling system, **Figure 21-4**. As the water pump pulley turns, impeller blades inside the water pump circulate coolant. As the water pump turns, coolant is pushed from the water pump outlet, through the engine and radiator, and then back to the water pump inlet. The water pump is bolted to the engine block.

Radiator hoses connect the engine to the radiator. See **Figure 21-5**. They are molded in a particular shape to allow their routing around obstructions. Hoses are attached to the engine and radiator with ***hose clamps***. **Figure 21-6** shows two types of hose clamps.

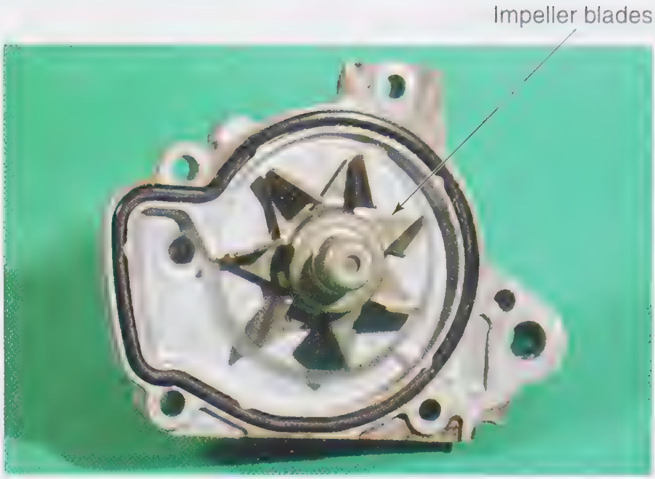


Figure 21-4. *Water pump blades propel coolant through the engine.*

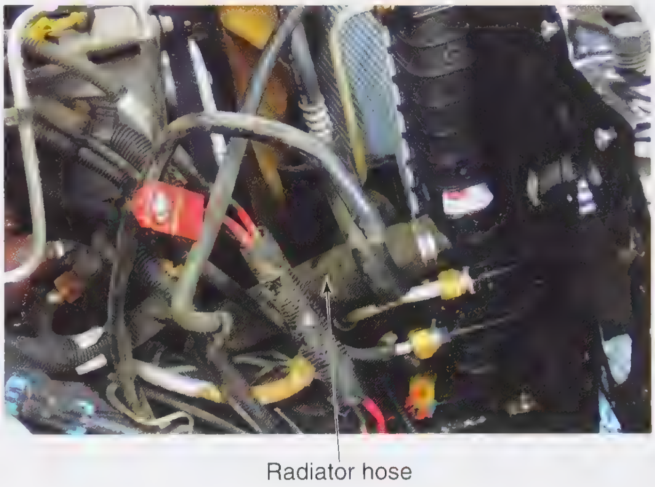


Figure 21-5. *Radiator hoses are molded and shaped to efficiently move coolant around the many obstacles found in an engine bay.*

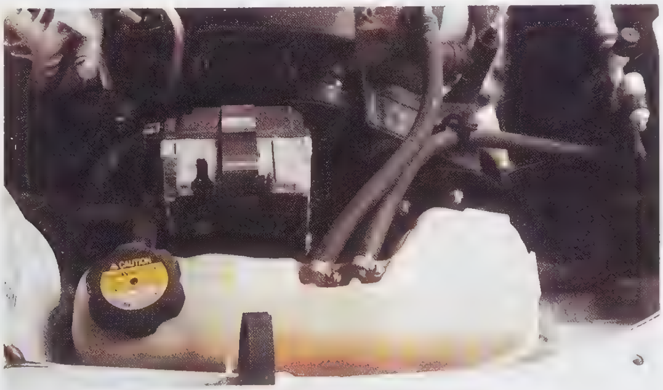


Figure 21-3. *The coolant recovery tank captures and stores coolant for use in the radiator.*

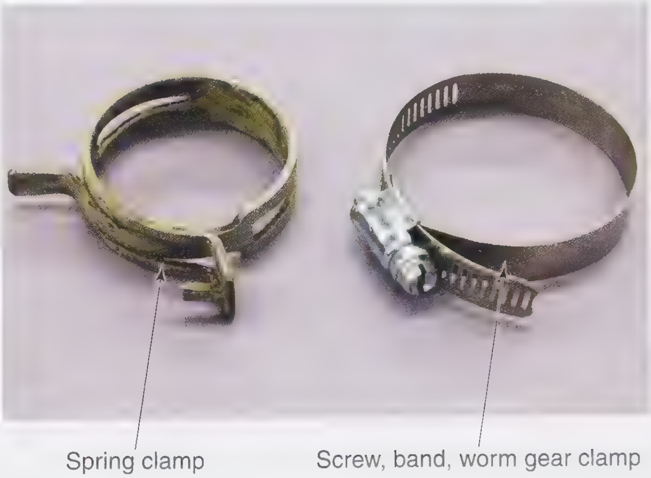


Figure 21-6. *Two types of hose clamps are shown here.*

The ***thermostat*** regulates coolant flow, allowing the engine to warm up quickly. When a cold engine is started, the thermostat, which is located in a coolant passageway between the radiator and engine, is shut. This prevents cold coolant from circulating through the radiator. Instead, the coolant circulates only inside the engine. When the coolant heats up to a set temperature, 160°F–220°F (71°C–104°C), the thermostat opens. The open thermostat allows heated coolant to begin circulating through the radiator. When the engine is shut off and the coolant cools to a temperature that is less than the set temperature, the thermostat closes. A cross section of a thermostat is shown in **Figure 21-7**.

The thermostat will cycle (open and close) during engine operation to maintain an optimal engine temperature. In effect, the thermostat acts as a temperature control valve. Hot coolant circulates to the radiator where it is cooled and returned to the engine block. When coolant temperature drops below a predetermined point, the thermostat closes and the cycle begins anew.

Keeping engine coolant at the desired temperature range is the thermostat's primary job. As an engine heats up during operation, the thermostat opens to keep the coolant within the desired temperature range. As engine coolant temperature rises, as it would during prolonged operation, the thermostat opens further.

The ***fan*** draws air through the radiator. When the vehicle is driven at highway speeds, enough air is usually forced over the radiator fins to cool the engine. However, when the engine is running and the vehicle is not moving, or not moving fast enough, cooling air must be pulled through the radiator by the fan.

A transversely mounted engine cannot use the engine pulleys to drive a fan at the front of the vehicle. Therefore, front-wheel-drive vehicles have an electric fan to pull air through the radiator. Rear-wheel-drive vehicles may also have an electric fan; most late-model, rear-wheel-drive cars do. Some vehicles may have two fans. One fan may operate whenever the air conditioning is switched on, while the other fan operates as needed to regulate engine temperature. The electric fan consists of a motor, fan blades, and shroud, **Figure 21-8**. The shroud is bolted to the radiator. The electric fan is controlled by a sensor exposed to coolant. When the coolant temperature reaches a predetermined level, the fan turns on. When the temperature of the coolant drops, the fan turns off.

In many rear-wheel-drive vehicles, the fan is bolted to a pulley on the front of the engine and is turned by a belt driven by the engine's crankshaft. The drive belts can be V-belts or a serpentine belt. A simple visual inspection of serpentine belt wear will alert you to the possible need for belt replacement. Signs that the serpentine belt is wearing are: more than three or four cracks per inch, a crack that is more than a half inch deep, frayed or missing pieces, or a shiny glazed appearance. See **Figure 21-9**. Engine-driven fans have a ***fan clutch***, which allows the fan to slow or stop rotation when enough air is being forced through the radiator to cool the engine. A belt-driven fan is shown in **Figure 21-10**.

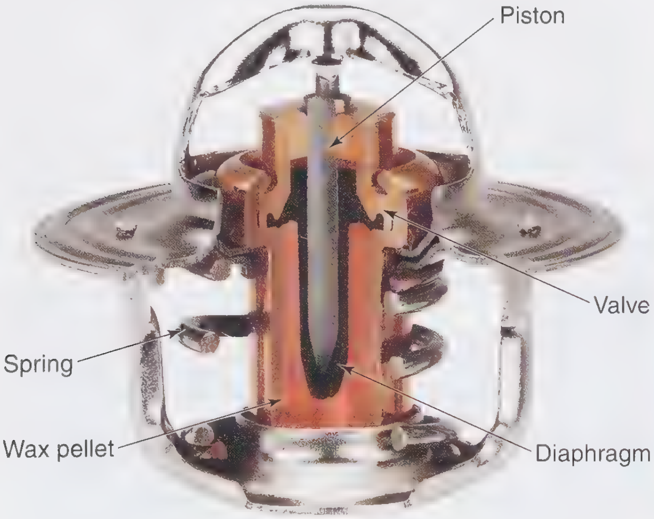


Figure 21-7. *This is a cross section of a thermostat. The thermostat will open when a predetermined coolant temperature is reached. (Gates)*

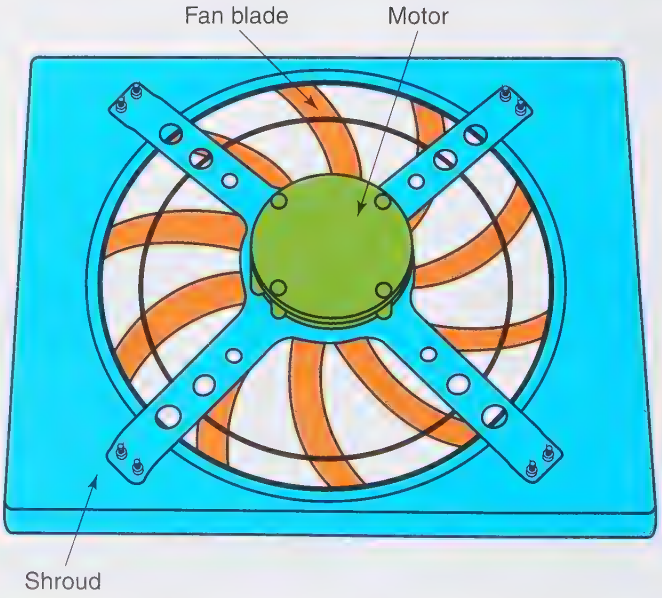


Figure 21-8. *An electric fan consists of a motor, fan blades, and shroud.*

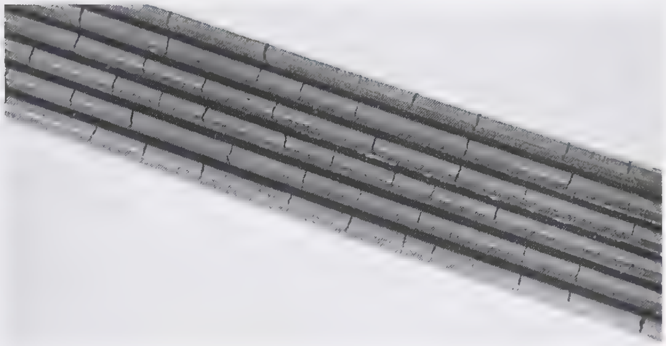


Figure 21-9. *Cracks indicate wear on this V-ribbed belt. If you find more than three or four cracks per inch, replace the belt. (Gates)*

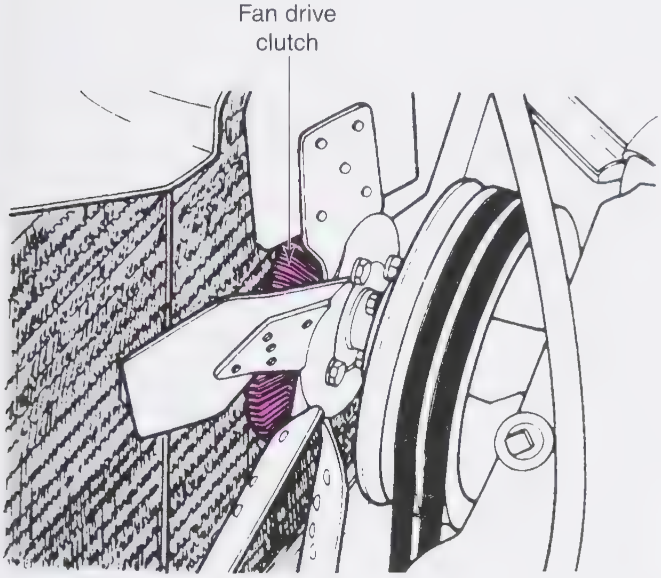


Figure 21-10. *This is a belt-driven fan and fan clutch from a rear-wheel-drive vehicle. (Ford)*

The fan shroud directs the airflow from the radiator to allow the fan to operate at maximum efficiency. The shroud, which is generally made of plastic, is bolted to the radiator. The fan shroud is an important part of an efficient cooling system.

An engine coolant temperature gauge allows the driver to monitor critical engine temperature. A gauge is shown in **Figure 21-11**. As the engine warms up, the needle gradually moves to the right. If the needle moves above the normal range, the engine is overheating. Some vehicles have warning lights in place of gauges. The warning light illuminates to indicate an overheating problem.

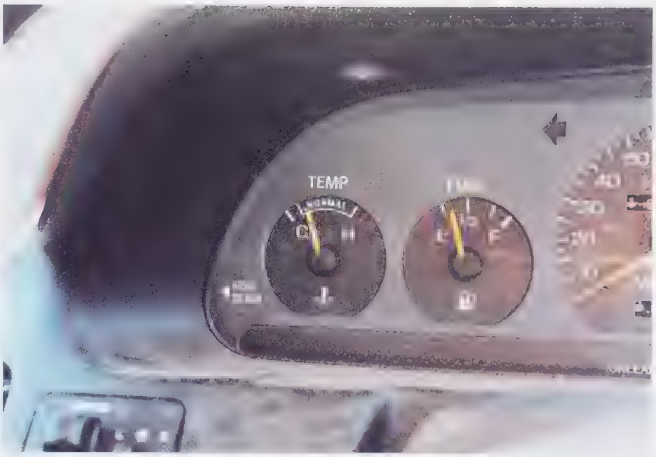


Figure 21-11. *Here is an engine temperature gauge. The engine is overheating if the needle swings to the H position.*

Cooling System Damage

The cooling system may be damaged in a collision. In most cases, damaged parts are replaced rather than repaired. There are two basic types of radiator damage. In the first type of damage, the radiator is leaking. Signs of this damage may be obvious: a puddle of coolant under the vehicle or a hole in the radiator itself. A leaking radiator will lose coolant and not maintain pressure. In the other type of radiator damage, the radiator does not leak. However, the radiator is bent and the mounting tabs may be broken or the fins may be bent. **Figure 21-12** shows radiator damage.

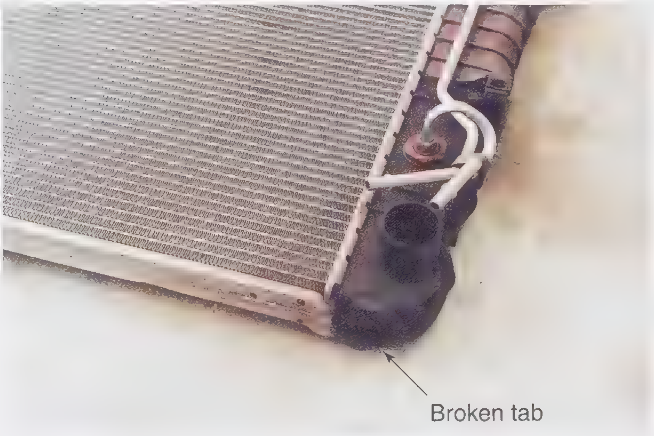


Figure 21-12. *This radiator was pushed back by a front impact. The mounting tabs, which fit into holes in the radiator support, were broken off by the impact.*

As the radiator support and radiator are pushed back by the force of a collision, the electric fan may be slammed against the engine. Damage includes broken mounting tabs, bent fan blades, or a crushed motor.

A front impact may push the radiator into an engine-mounted fan. Fan blades may be bent or broken. The fan clutch may also be damaged. **Figure 21-13** shows a damaged fan. Do not attempt to straighten bent fan blades.

As the radiator support moves in a collision, the fan shroud may contact the fan or engine block. The shroud may be cracked or cut. Inspect the shroud for damage and replace it if needed.

A damaged coolant recovery tank may leak or mounting tabs may be broken. Look for leaks and grab the tank to see if it is loose. In a closed system, be sure the recovery tank holds pressure.

A collision that damages an engine mounted fan may also damage the water pump. A damaged water pump may leak. If the bearings are damaged, the pump will make a grinding sound as the pulley turns. To check for damage, watch the pulley as it turns. A bent pulley or pulley mount will cause the pulley to wobble as it rotates. Damaged pulleys are not repaired; they are replaced. Hoses may be cut as engine components shift in a collision. A cut hose will leak. A belt may also be cut during a collision. Always check belts for cuts or gouges.

Cooling System Service

This section explains how to inspect and replace cooling system components. Cooling system service involves checking for leaking hoses, checking the strength of the coolant, mixing the coolant, draining and filling the radiator, fan removal, water pump replacement, and radiator removal and installation.

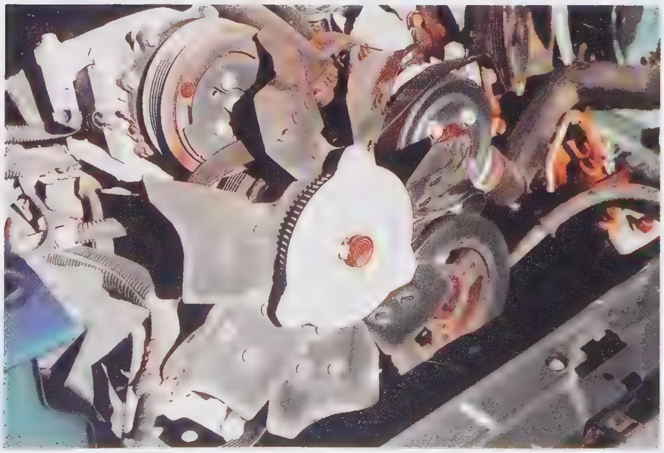


Figure 21-13. *This fan has bent blades.*

Checking Coolant Hoses

Cooling and heating system hoses deteriorate with age. **Figure 21-14** shows how to check a hose. Feel the hose for softness, brittleness, and leaking coolant.

Often, you will not be able to see what you are working on. Feel the hose to find the wetness of leaking coolant. Only touch the radiator hoses after the engine has cooled. The highest point on the hose that is wet is the location of the leak. Always replace a soft, brittle, or leaking hose.

Removing and Replacing Hoses

The first step in hose removal is to loosen the hose clamps. Some hose clamps are secured with screw-type clamps. The screw bites into slots in the strap portion of the clamp. Removal and installation simply requires turning the screw. Loosen the screw and push the hose clamp back toward the hose. Other clamps do not use a screw. Instead, they rely on spring pressure to secure the hose. To remove this type of clamp, use pliers to move the flanges toward each other. **Figure 21-15** shows this setup. When the flanges are moved together, the clamp can be removed. After the clamps have been removed, the hose can be pulled off its fittings. Twisting may be required to remove the hose. Be careful not to damage the hose fitting on the radiator.

To install a new hose, first slide the hose clamps over the hose then position the hose where it belongs on the engine. Slide the hose over both hose fittings. Push the hose as far as it will go onto the hose fitting, usually until the end of the hose covers the entire hose fitting. Hose fittings have a slight flare at the end. Position the clamp until it is between the end of the hose and the flare—never position the clamp on the flare.

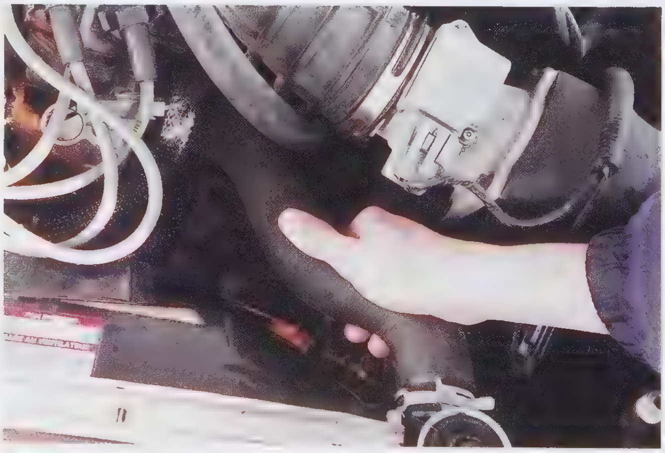


Figure 21-14. *Squeeze the hose and feel for softness, brittleness, or leaking coolant. Do not try this on a hot engine.*

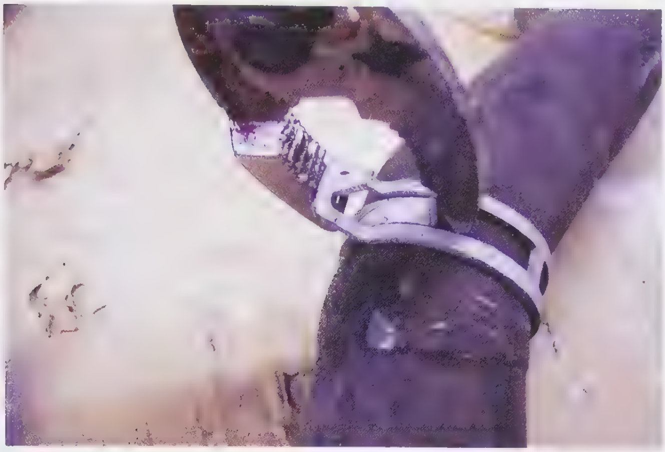


Figure 21-15. *Pliers can be used to remove a spring-type hose clamp.*

Make sure there are no kinks in the hose. The clamps may need to be rotated to gain access for tightening.

Checking and Mixing Coolant

A ***hydrometer*** measures the specific gravity (or relative density) of liquids. In automotive applications, it is used to measure the concentration of antifreeze, as shown in **Figure 21-16**. With this device, the freezing temperature of the coolant can be determined. Most vehicles use a coolant with a –40°F (–40°C) freezing point.

Antifreeze should be mixed with distilled water to give the coolant the proper boiling and freezing points. The mixing ratio is one part antifreeze to one part water. Mix the water and antifreeze before adding the coolant to the radiator. Some antifreeze comes premixed with water in the proper ratio for coolant.

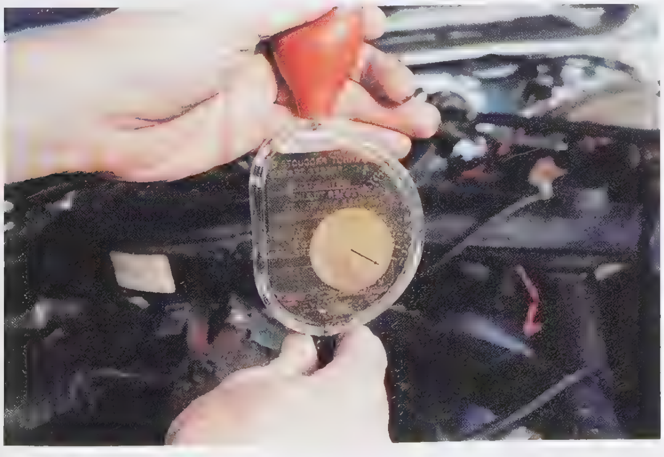


Figure 21-16. *A hydrometer is used to determine the freezing point of coolant.*

WARNING

Most antifreeze is poisonous. It is fatal to both humans and animals if ingested. Always ensure that antifreeze is properly stored in sealed containers and follow the correct disposal procedures.

Inspecting and Straightening Radiator Fins

Radiator or condenser fins are often flattened when a front impact pushes a condenser into the radiator or when the radiator jams against the fan or fan motor. Flattened fins do not efficiently exchange heat with air. If the condenser tubes, radiator tubes, or side tanks are undamaged, but the fins are flattened, repair of the condenser or radiator requires straightening the fins.

A fin comb has various sets of plastic teeth. Select the set that matches the distance between the undamaged radiator fins. Place the teeth between the fins away from the damage. See **Figure 21-17**. Pull the fin comb into the damaged area to raise and straighten the fins. Continue combing until all the damaged fins are straightened.

Draining the Radiator

Coolant must be drained if the radiator is to be replaced. Allow the engine to cool before attempting to drain the coolant. Hot coolant is under pressure and can cause serious burns. Do *not* open the system until the engine is cool and the system is not under pressure. You can squeeze a radiator hose to check for pressure. To drain a radiator, either open the drain valve at the bottom of the radiator or remove the lower radiator hose. Collect the coolant in a container for proper disposal. Removing the radiator cap allows faster draining.

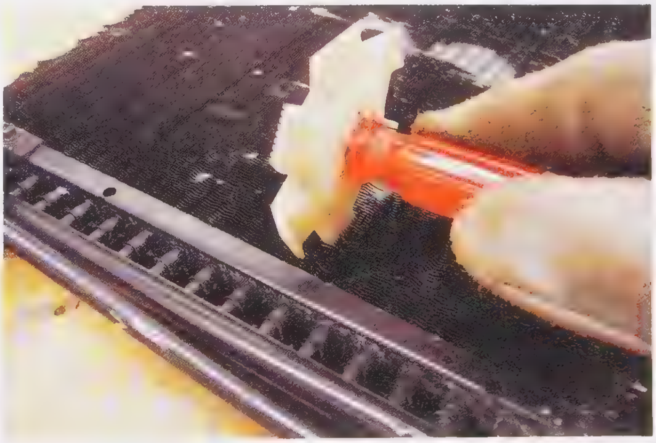


Figure 21-17. *Insert the proper fin comb between the good fins and pull the fin comb tool through the damaged, flattened fins.*

Filling the Radiator

If the radiator fill neck is higher than the engine, adding coolant is simply a matter of filling the radiator with coolant and then starting the vehicle. Add more coolant as the level drops in the radiator. Replace the radiator cap and fill the coolant recovery tank. As the engine warms, the coolant will be drawn from the recovery tank into the radiator.

If the radiator fill neck is below the engine, air bleeding is required. Check the vehicle's service manual. During bleeding, air trapped in the engine's coolant passages is released by opening an air bleed valve.

Fan Removal

The fan may need to be removed for water pump or radiator replacement. There may be a nut on the back side of the fan that must be loosened to remove the fan. Unfortunately, turning this nut may cause the pulley to turn. One type of fan requires that a fan clutch tool be used to hold the fan while the nut is turned. Another method utilizes special tools to hold the pulley stationary as the nut is turned.

Begin electric fan removal by disconnecting the battery. Next, disconnect the electrical line from the fan motor. The fan is attached to the back of the radiator with four bolts. Access to these bolts is usually limited. A 1/4" drive air ratchet is the best tool to use when removing these bolts. The air ratchet is small enough to fit into the constricted area. After removing the bolts, lift the electric fan out of the engine compartment. When installing an electric fan and radiator, it is often best to bolt the fan to the radiator *before* the radiator is installed. This will work on vehicles where there is enough clearance between the engine and the radiator support. If there is not enough clearance to maneuver the fan-radiator assembly into place, install the radiator first and then bolt the electric fan to the radiator. Finally, connect the electrical wire to the fan motor and reconnect the battery.

Water Pump Replacement

A rear-wheel-drive vehicle with a longitudinally mounted engine can be hit hard enough to damage the water pump. See **Figure 21-18**. The water pump is bolted to the front of the engine block in these vehicles. Begin water pump replacement by draining the radiator and removing any obstructions. Also, remove the engine belt(s). Unbolt the water pump from the block. There will be a gasket between the pump and the block. Remove the entire gasket. It may require vigorous scraping to remove all gasket residues off the engine block. Next, install the new gasket and pump. A gasket sealer may be used. Torque the pump bolts to the required value. Replace any parts that were removed and refill the cooling system. On transversely mounted engines, the water pump is located under the timing belt cover. Damage to the water pump on this type of engine would also cause extensive engine damage. The cost to repair this much engine damage usually exceeds the value of the vehicle.

Removing and Replacing a Radiator

Electrolysis, the chemical reaction between antifreeze and aluminum, causes corrosion. As a radiator ages, deposits of calcium, lime, and the by-products of corrosion build up and block internal passages. A collision can easily render an already weakened radiator unusable. **Figure 21-19** shows a vehicle with radiator damage.

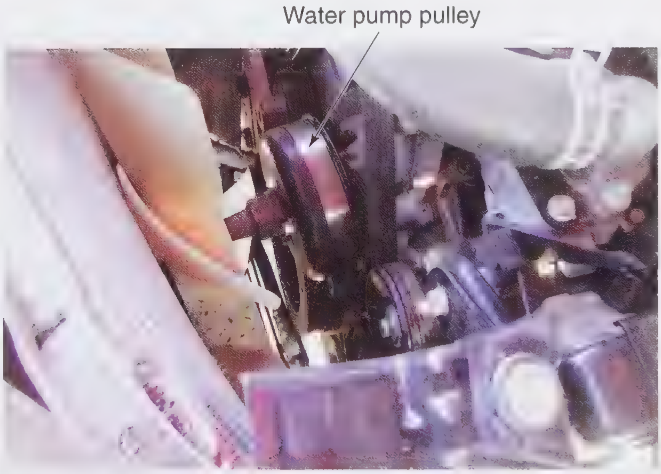


Figure 21-18. *The water pump is damaged on this front hit pickup truck. Notice that the water pump pulley is not in alignment with the other pulleys.*

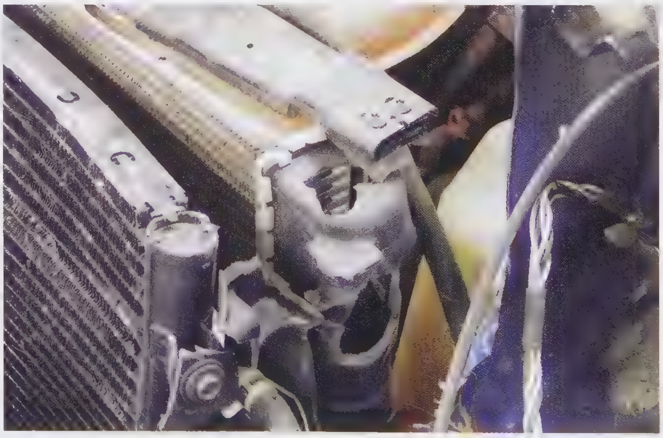


Figure 21-19. *This damaged radiator needs to be replaced.*

The following are steps used to remove and replace the radiator:

1. Disconnect the negative battery terminal.
2. Drain the radiator.
3. Disconnect the wire to the electric fan motor, if necessary.
4. Remove the fan shroud, if it is not part of the fan assembly.
5. Unbolt the electric fan from the radiator and pull out the electric fan. Remove an engine-mounted fan, if needed.
6. Remove the radiator hoses.
7. Remove the transaxle or transmission cooling lines, if needed.
8. Unbolt the radiator hold-downs.
9. Pull out the radiator.
10. Check the radiator mounts. Usually these are pegs on the radiator that slip into rubber grommets.
11. Install the new radiator.
12. Bolt the radiator in place.
13. Reinstall the transaxle or transmission cooling lines, if necessary.
14. Reinstall the radiator hoses.
15. Reinstall the fan, if needed.
16. Reconnect the electric wire to the electric fan.
17. Reinstall the shroud, if necessary.
18. Reconnect the negative battery terminal.
19. Fill the radiator and check the cooling system for leaks.

Heating System

The ***heating system*** works with the cooling system. The heat from the coolant is used to warm the vehicle interior. The warm air produced by the heating system is also used to defrost the windshield.

Heating System Parts

The heater core looks and functions exactly like a mini-radiator, and just like a radiator, the heater core has tubes and fins, see **Figure 21-20**. As heated coolant passes through the radiator, the fins absorb heat from the coolant and release it to air passing over the fins. If needed, the heater core can be repaired or replaced. A heater fan draws air either from inside or outside the vehicle and forces that air through the heater core. Air is warmed by the transfer of heat from the fins on the heater core. The warm air is moved through heater ducts that direct air toward the passengers or windshield. Doors inside of the ductwork are opened or shut to divert the air to the desired location. The direction of air movement is determined by the control settings. Moving the control knobs operates doors in the ductwork. The doors can be controlled by cables or vacuum motors. Coolant from the engine is moved to and from the heater core through heater hoses. The heater hoses are attached to the core by hose clamps.

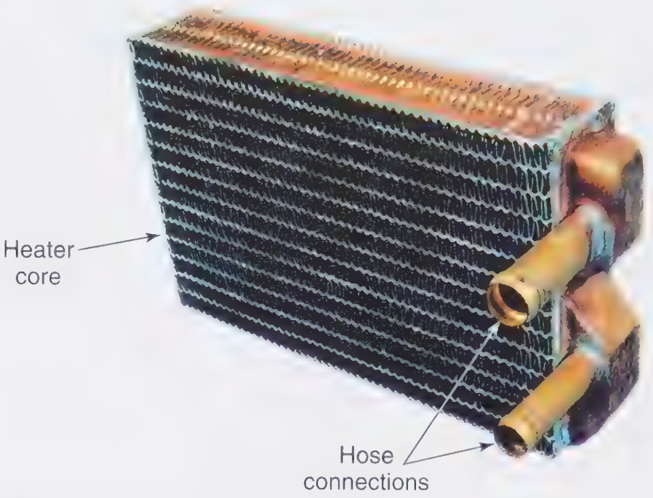


Figure 21-20. *A heater core looks and functions exactly like a mini-radiator.*

Heating System Damage

Because the heating system is in the engine compartment, cowl, and passenger compartment, collision damage is rare. If the heating system is damaged, the vehicle is generally so extensively wrecked that it will be declared a total loss.

Air Conditioning System

The ***air conditioning system*** uses a refrigerant to cool the interior of the vehicle. The refrigerant circulates in the system and takes turns *absorbing* and releasing heat. When the refrigerant absorbs heat, it changes from a liquid to a gas, or ***evaporates.*** When the refrigerant *releases* heat, it changes from a gas to a liquid, or ***condenses.*** Heat in the passenger compartment is absorbed by the refrigerant, cooling the inside of the vehicle. As the refrigerant moves through the system, it changes from a liquid to a gas and then back to a liquid. This change from liquid to gas, or gas to liquid, is known as a phase change. The refrigerant goes through this cycle over and over.

An overview of an air conditioning system is shown in **Figure 21-21**. Notice that there are four different refrigerant states in the system: low-pressure liquid, low-pressure gas, high-pressure liquid, and high-pressure gas. Each refrigerant state/phase change is controlled by a system component. An air conditioning system has high-pressure and low-pressure sides. By alternating between the two sides, refrigerant can alternate between absorbing heat from the vehicle interior and releasing that heat through the condenser mounted ahead of the radiator.

R-12 refrigerant was installed by vehicle manufacturers before 1994. This refrigerant was found to damage the ozone layer. The ***ozone layer*** is a blanket of ozone (O_3) molecules in the earth's atmosphere. These molecules block some of the ultraviolet (UV) light from the sun. The production of R-12 in the US ceased in 1995. Since 1994, manufacturers have installed R-134a refrigerant in vehicle air conditioning systems. R-134a is less harmful to the ozone but it is still a problem, and under no circumstances should any refrigerant be intentionally discharged into the atmosphere. Automakers will begin to phase it out in favor of HFO1234yf.

R-12 and R-134a air conditioning system components are not interchangeable. Additionally, R-12 and R-134a refrigerants cannot be mixed. However, an R-12 system can be retrofitted to use R-134a refrigerant. The air conditioning system requires oil to lubricate the compressor. The oils in R-12 and R-134a are different. Do not mix these oils.

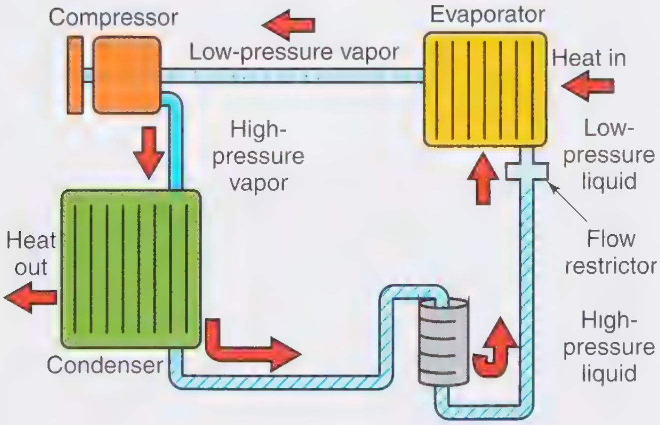


Figure 21-21. *This is a generalized view of how the refrigerant moves and changes state in an air conditioning system. Starting at the compressor, the high-pressure vapor moves to the condenser. The refrigerant changes to a high-pressure liquid in the condenser. This high-pressure liquid changes into a low-pressure liquid at the flow restrictor. The refrigerant changes into a low-pressure vapor in the evaporator. The cycle begins again as the low-pressure vapor moves to the compressor.*

Air Conditioning System Parts

The individual components of a typical air conditioning system are:

- Compressor.
- Condenser.
- Flow restrictor.
- Evaporator.
- Accumulator or receiver/drier.
- Refrigerant lines.
- Service fittings.
- Pulleys and belts.
- Controls.

The ***compressor*** changes the low-pressure refrigerant gas in the system into a high-pressure gas. The low-pressure gas contains heat absorbed from inside the passenger compartment. The compressor is mounted on the engine and is driven by a belt and pulleys, **Figure 21-22**. The belt may be a V-belt or a serpentine belt. From the compressor, the high-pressure gas enters the condenser.

The ***condenser*** has tubes and fins like a radiator, and it functions like a radiator to cool the refrigerant. The condenser is located at the front of the vehicle, ahead of the radiator, **Figure 21-23**. As the high-pressure gas moves through the condenser, the heat absorbed from inside the vehicle is transferred to the fins on the condenser. Air moving over the fins removes this heat. The air movement is caused by driving the vehicle or by the fan pulling air through the condenser and radiator. As the high-pressure gas is cooled, it condenses, turning into a high-pressure liquid.

The ***flow restrictor*** allows a certain amount of liquid to pass through a small opening into a larger area. With the increased area to expand into, the high-pressure liquid changes into a low-pressure liquid. The flow restrictor also regulates the amount of refrigerant that enters the evaporator.

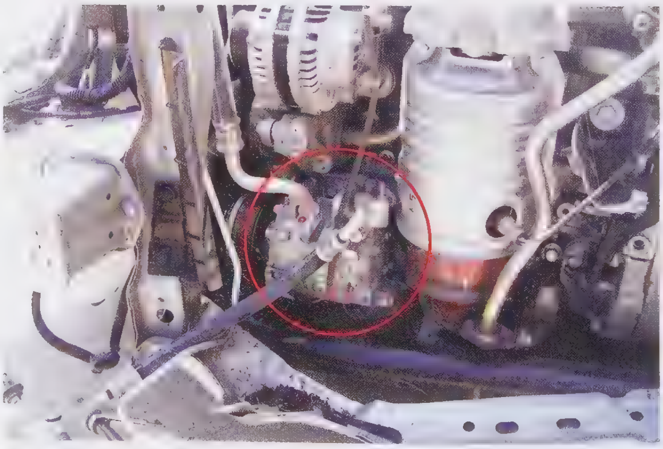


Figure 21-22. *The compressor is the "heart" of the air conditioning system.*

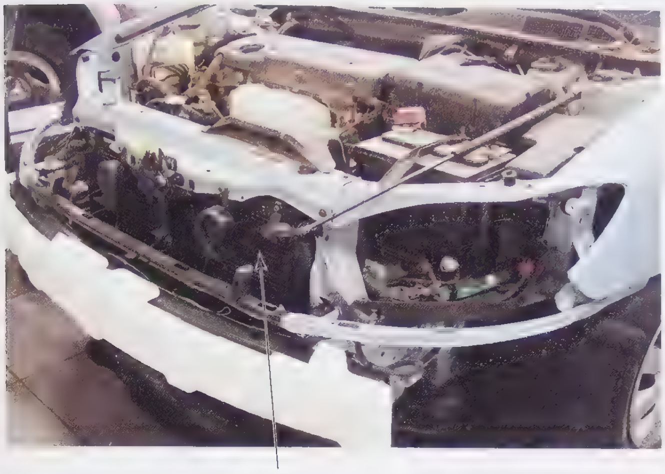


Figure 21-23. *The condenser is located in front of the radiator.*

An ***evaporator*** is a system of tubes and fins located inside the passenger compartment, **Figure 21-24**. Warm air passes over the fins. The low-pressure liquid refrigerant circulating through the evaporator absorbs this heat and phase changes into a gas. This low-pressure gas is pulled to the compressor by suction. The surface of the evaporator feels cold because heat is being absorbed by the refrigerant. Air blowing over the evaporator is cooled. This cold air is directed into the passenger compartment, cooling the vehicle's interior. Also, as the air is cooled, moisture in the air condenses. This condensed moisture is collected at the bottom of the evaporator and discharged outside the vehicle. This is why an air-conditioned vehicle may have a puddle of water under it.

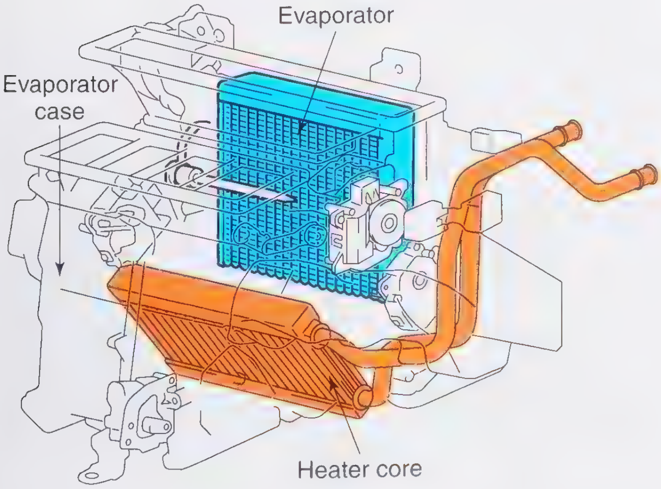


Figure 21-24. *An evaporator uses refrigerant to absorb heat out of the passenger compartment.*

Moisture in the refrigerant may damage the compressor. The ***accumulator,*** or ***receiver/drier***, acts as a reservoir for the refrigerant and also removes moisture from the refrigerant in the system. The moisture is removed by a desiccant. A ***desiccant*** is a chemical that absorbs moisture.

There are two types of ***refrigerant lines***—metal tubes and flexible rubber hoses. The metal tubes and rubber hoses form airtight connections between air conditioning system components. The connections can be made with nuts or with garters. See **Figure 21-25**. A garter spring looks like a ring or circle made out of a coil spring. They are used to provide an even radial force around an object. In refrigerant applications the male end of the coupling is inserted into a female flared end. The union is held together by the garter spring which prevents uncoupling by tightly gripping the flared end of the female connector.

With either type of connector, O-rings seal the line, preventing leakage of refrigerant. Garters may also have a release clip on top of the connection.

Refrigerant is added to or removed from the air conditioning system through ***service fittings.*** Push-on service fittings, also called quick-disconnect fittings, are used on R-134a systems. See **Figure 21-26**. The low-pressure side of the system has a service fitting that is a different size from the service fitting on the high-pressure side. This prevents a mix-up in connectors. R-12 systems use Schrader valves, which look like tire valves. The ***Schrader valves*** may be different sizes, again, to prevent a cross connection of high- and low-pressure sides of the system. Schrader valves have screw-on connectors.

The controls for an air conditioning system are shown in **Figure 21-27**. These are located in the passenger compartment.

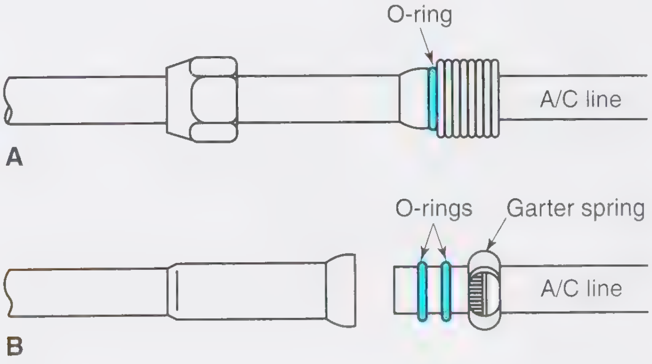


Figure 21-25. *A—This is an air conditioning line nut connection. Notice the O-ring. B—This is a garter connection. The two ends slide together and are held by a circular spring. Notice the O-rings.*

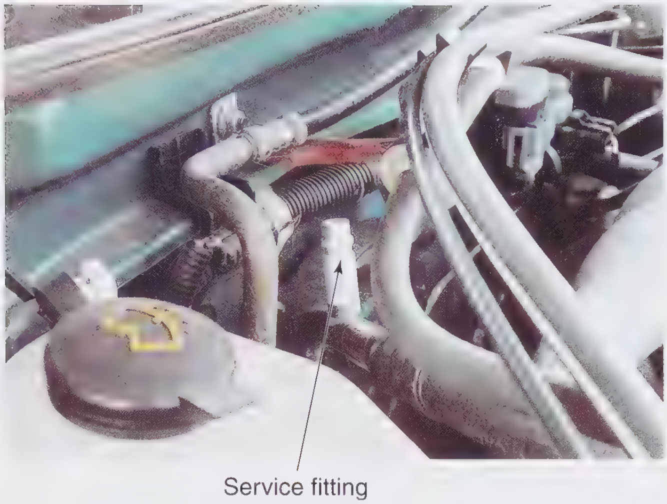


Figure 21-26. *The cap has been removed to better show this push-on fitting.*

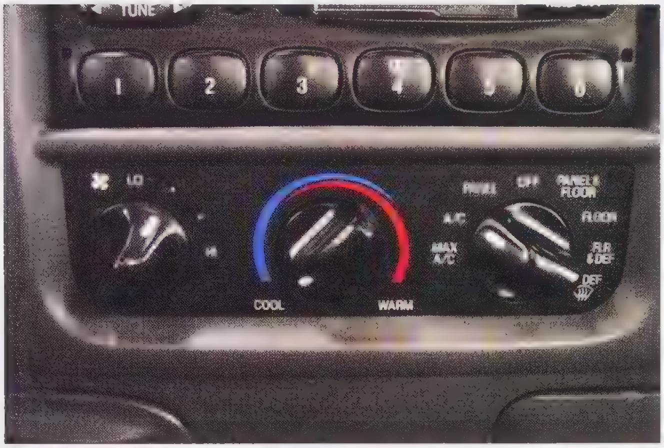


Figure 21-27. *The fan is always on low unless the control on the right is set to* off. *The controls are set for the A/C system to operate, but not at maximum cool.*

Air Conditioning System Damage

Some air conditioning system components may be damaged in a collision. The commonly damaged parts are:

- Condenser.
- Lines.
- Pulley and belt.
- Accumulator (receiver/drier).

The condenser is often damaged in an accident because it is located just behind the grille. A damaged condenser is shown in **Figure 21-28**. The front bumper moved back when this truck rear-ended another truck. The condenser tubes did not break, and refrigerant was not lost, but this condenser must be replaced.

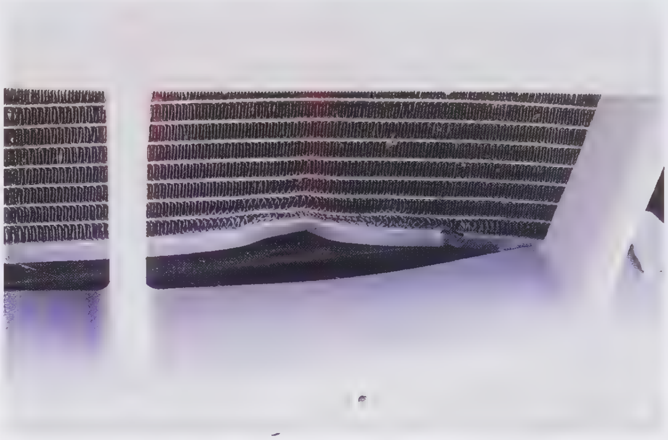


Figure 21-28. *This condenser is bent but not leaking.*

Another type of damage is shown in **Figure 21-29**. Flattened fins will not allow air to pass through the condenser. The fins can be straightened. However, if the condenser tubes are broken, the refrigerant will leak out. Damage of this type results in a depressurized and nonfunctioning air conditioning system.

A damaged metal line is shown in **Figure 21-30**. Damaged lines may leak. Rubber hoses may also be cut or nicked.

The compressor pulley may be damaged in a collision. Look for wobble as the pulley rotates. Belts may also be cut by an impact. Check the belts for cuts or cracks.

The accumulator must be replaced if the air conditioning system has been open for more than an hour. With exposure to air, the desiccant in the accumulator will be used up and no longer will be capable of protecting the air conditioning system.

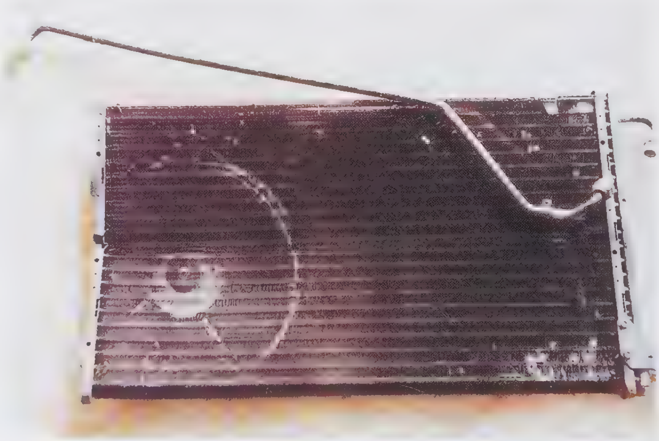


Figure 21-29. *As the result of being pushed into the fan, this condenser has flattened fins.*

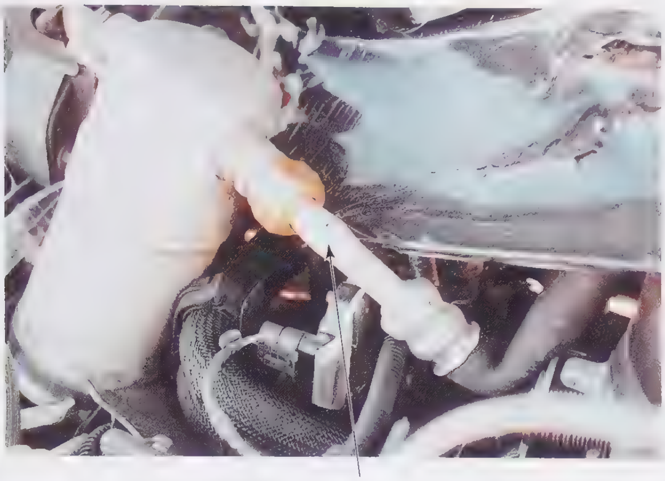


Figure 21-30. *This air conditioning line is bent.*

If the condenser or air conditioning lines were torn in a crash and refrigerant leaked out, the system is considered open. Therefore, the accumulator must be replaced.

NOTE

The Clean Air Act, enforced by the Environmental Protection Agency, has set regulations for the proper use of refrigerants and established penalties for their misuse.

WARNING

Refrigerant is dangerous if it contacts skin or eyes. Use extreme caution when working on an air conditioning system. Also, technicians working on air conditioning systems must be certified in refrigerant recovery and recycling.

Air Conditioning System Service

Air conditioning system service includes repairing or replacing damaged parts. Refrigerant must be removed from a system to replace the air conditioning system components. This process is called recovery. Refrigerant removed from the system must be stored and may be reused. This process is called recycling. The two types of refrigerants, R-12 and R-134a, cannot be stored together. They must be kept separate. Some recovery/recycle equipment is set up just for R-12 or R-134a. Other equipment can handle both types. **Figure 21-31** shows a typical recovery/recycle machine. This machine can be used to remove and store refrigerant, as well as recharge the refrigerant. This machine is also capable of drawing out all the moisture from an air conditioning system.

Condenser Service

This section explains various operations involved in servicing the condenser. The air conditioning lines may be damaged in a collision along with the condenser. A damaged system with a hole will be empty of refrigerant. A bent condenser may still hold refrigerant. The type of refrigerant must be determined before recovering the refrigerant.

Checking Refrigerant Type

When refrigerant is removed from an air conditioning system, the refrigerant must be recovered. Recovering means that the refrigerant is captured and stored so it can be reused, or recycled. This procedure is discussed later in this chapter. Before recovery, the refrigerant should be checked to determine what type it is. A ***refrigerant identifier*** is a machine that is connected to a service fitting. It determines whether the refrigerant is R-12, R-134a, or an unknown refrigerant. The unknown refrigerant may have been added during a previous air conditioning system repair. An unknown refrigerant should be considered contaminated and not be reused. Store the contaminated refrigerant in a separate container.

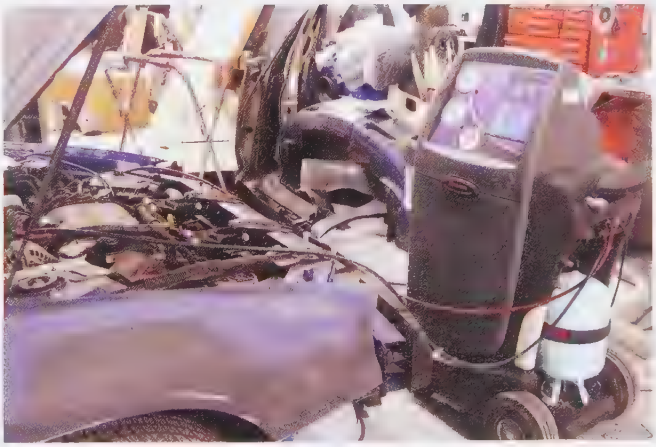


Figure 21-31. *This R-134a recovery/recycle machine has lines to attach to the vehicle service fittings, a recovery tank to store refrigerant, and gauges to display the pressure inside the A/C system.*

WORKING GREEN

The processes of refrigerant recovery, recycling, and reclaiming may sound similar, but they are quite different.

To *recover* is to remove refrigerant in any condition from a system and store it in an approved external container. Recovered refrigerant must not be returned to a motor vehicle air conditioning system (MVAC) without first being recycled or reclaimed.

To *recycle* is to clean refrigerant for reuse by separating the oil and removing moisture by passing it through one or more filter driers. Recycled refrigerant may be returned to a MVAC. In recycled refrigerant, the levels of contaminants such as moisture, refrigerant oil, and non-condensable gasses are limited to the levels set by the Society of Automotive Engineers.

To *reclaim* is to process refrigerant to a level equal to new product specifications as determined by chemical analysis. Reclaimed refrigerant must meet standards set forth by the Air Conditioning and Refrigeration Institute in ARI standard 700-93. Reclaimed refrigerant is intended for sale and may be used in any application.

Connecting Service Fittings

Service fittings allow refrigerant to be recovered from or added to the air conditioning system. They also permit the hookup of manifold gauges. These gauges are hooked up to the high and low pressure sides of the air conditioning system. The gauges will indicate the pressure on each side. The center hose is used to add refrigerant.

The service fittings for R-12 systems and R-134a systems are different. As mentioned previously, the R-12 systems use a Schrader valve. The Schrader valve has outside threads to which the connector is attached. Once the connector is tightened, no leakage will occur at the valve. To attach to a Schrader valve, simply find the properly sized connector and screw it in place. R-134a systems use a quick-disconnect fitting similar to the connector used on a compressed air line. The connector locks in place, forming an airtight seal. With both Schrader valves and quick-disconnect fittings, once the connection is made, the manifold gauge valves can be opened for recharging or evacuating.

A recovery/recycle machine has connectors to attach to the appropriate service fitting. See **Figure 21-32**. Some machines have valves in between the connectors and the machine. When the connector is attached to the service fitting, opening the valve allows the refrigerant to flow.

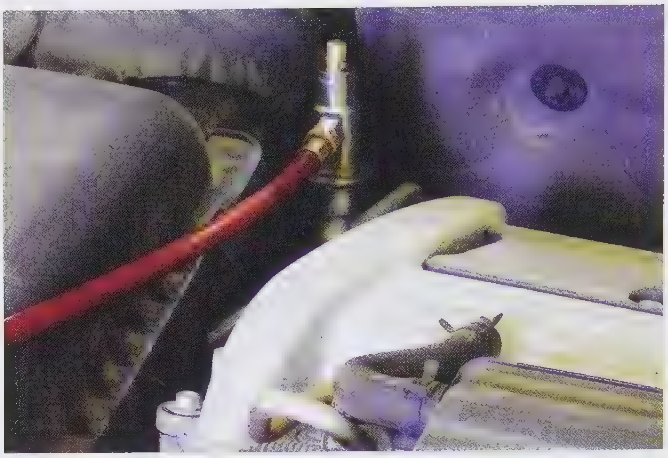


Figure 21-32. *This is the attachment point of a connector to a service fitting.*

Separating and Connecting Air Conditioning Lines

Air conditioning lines can be held in place with nuts or garters. Use two wrenches when connecting or disconnecting lines with nuts to prevent twisting. **Figure 21-33** shows how to remove a garter. Fit the tool over the line so that the flange of the tool will push on the garter spring. Push on the garter spring and then pull the two lines apart. To reconnect, slide the lubricated lines together with a slight twist as the lines meet.

Plugging Air Conditioning Lines

Moisture can cause acids to form in an air conditioning system. These acids will damage the compressor. Whenever the air conditioning system is opened for service, the air conditioning lines should be capped with airtight plugs. Cap the lines as soon as the system is opened. Tight-fitting plastic plugs may be used or plastic wrap can be placed over the opening and held in place with rubber bands.

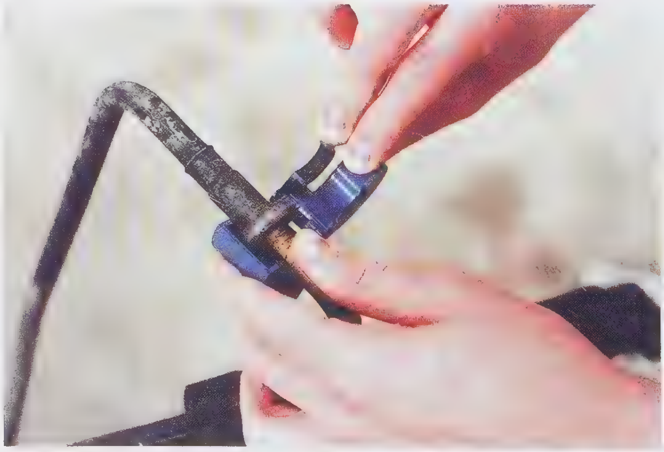


Figure 21-33. *The flange is on the upper side of the tool. Push the flange under the spring inside the garter and pull the lines apart.*

If the system has a hole and all refrigerant has leaked out, replace the accumulator as other components are replaced. Plug or reconnect all components to keep moisture out until the system is recharged.

Installing O-rings

O-rings are vital to air conditioning system operation. O-rings form the seal that keeps refrigerant inside the system. O-rings are easily damaged by abrasion, and the damage is not obvious. Replacement of O-rings during service prevents leakage of refrigerant. Replace O-rings whenever air conditioning lines are disconnected. Be sure the replacement O-rings are the proper type and size. See **Figure 21-34**. Lubricate the new O-rings with the appropriate air conditioning system oil.

Replacing the Condenser

The condenser is always in front of the radiator, and is therefore the most commonly damaged component of an air conditioning system. To replace the condenser, first check to see if the air conditioning system is charged. If the system contains refrigerant, the refrigerant must first be recovered, as described later. Next, disconnect the negative battery cable and electric fan wire. On some vehicles removal of the grille allows better access to the condenser. However, the condenser may only be accessible after the radiator is removed. Drain and remove the radiator, if required. Disconnect the air conditioning lines from the condenser and plug them to prevent system damage. Unbolt and remove the condenser. Install the new condenser and new O-rings on the air conditioning lines. Connect the lines. Install the radiator and refill the cooling system. Finally, evacuate and recharge the air conditioning system.

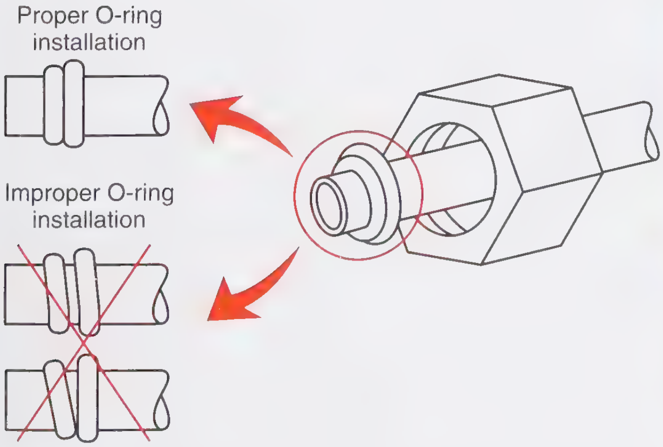


Figure 21-34. *Position O-rings properly to prevent leaks.*

Air Conditioning System Recovery, Evacuation, and Recharging

The following procedure is followed when an air conditioning system must be opened to replace a part.

1. Identify the refrigerant type.
2. Hook up the appropriate connectors to the service fittings.
3. Open the valves on the manifold gauge set and drain the refrigerant into the recovery tank. **Figure 21-35** shows a charging station. This machine automatically drains, evacuates, and recharges the air conditioning system.
4. Once the system is empty, the pressure gauge will read 0 psig or less (a vacuum). Wait about ten minutes and then shut off the machine.
5. Replace air conditioning system components as needed. Be sure to use new O-rings. Tighten all connectors to specifications. If the compressor is replaced, oil should be added to the compressor before it is installed. Check the service manual for instructions.
6. Evacuate the system. ***Evacuation*** means that the system is held under a vacuum for at least thirty minutes to pull all the water out of the system. Once the evacuation is complete, the refrigerant can be returned or added to the system. If the A/C system cannot make a vacuum during evacuation, there is a leak somewhere that allows air into the system. The leak could be at a loose connection, a broken hose or line, a damaged O-ring, or a hole in the condenser or evaporator. Find and fix the leak before proceeding.
7. Recharge the system with refrigerant and oil. A charging station adds the proper amount of refrigerant and oil to the system.

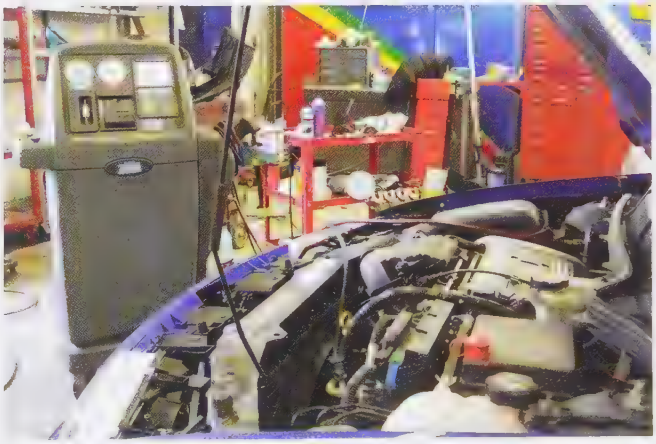


Figure 21-35. *This is how this recovery/recycle machine looks when it is hooked up.*

8. Close the valves on the manifold gauge set.
9. Remove the connectors from the service fittings.
10. Start the engine and turn on the air conditioning. Check air temperature at the vents inside the vehicle with a thermometer, as shown in **Figure 21-36**.

The temperature of the air discharged from the air conditioning vents depends on the ambient temperature and relative humidity. Higher ambient air temperature and higher relative humidity mean the discharge air temperature will be higher. For example, at 70°F (21.1°C) and 20% relative humidity, the discharge air temperature should be 43°F (6.1°C). At 90°F and 80% relative humidity, the discharge air temperature should be 65°F (18.3°C). Consult a manufacturer's chart to find the minimum discharge air temperature.

Check for Air Conditioning System Leaks

Refrigerant leakage will result in air conditioning system failure. After air conditioning system service, the entire system should be checked for leaks. An ***electronic leak detector*** can be used to check for escaping refrigerant. All connectors should be probed. The detector will signal if escaping refrigerant is discovered. See **Figure 21-37**.

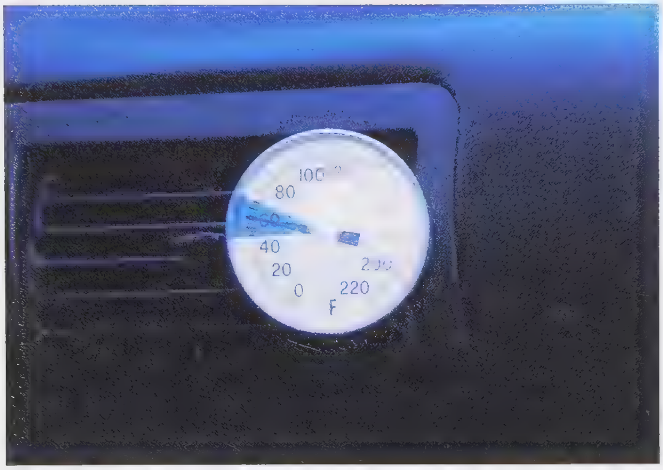


Figure 21-36. *A thermometer in a vent can be used to check the temperature of the discharge air.*

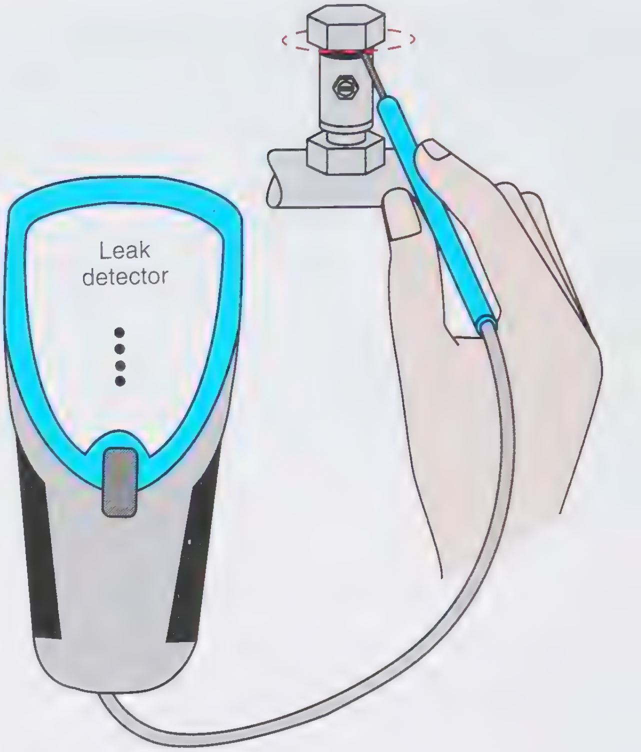


Figure 21-37. *All connections should be tested for leaks.*

Summary

- High engine temperature causes engine damage.
- Cooling system failure is usually caused by loss of coolant or obstruction of coolant flow.
- Proper cooling system function is essential for long engine life.
- To function properly, the cooling system should be sealed and full of coolant.
- The thermostat regulates coolant flow.
- Keeping engine coolant in the desired temperature range is the thermostat's primary job.
- Front end collisions often damage cooling and air conditioning system components.
- In most cases, damaged parts are replaced rather than repaired.
- The heating system works with the cooling system.
- A hydrometer is used to measure the concentration of antifreeze.
- The air conditioning system uses a refrigerant to absorb heat from the passenger's compartment.
- To function properly, the air conditioning system must be sealed and full of refrigerant.
- Heat in the passenger compartment is absorbed by the refrigerant, cooling the inside of the vehicle.

- Refrigerant must never be intentionally discharged into the atmosphere.
- The compressor changes low-pressure refrigerant gas in the system into a high-pressure gas.
- The condenser functions like a radiator to cool the refrigerant.
- The condenser is often damaged in a collision because it is located just behind the grille.
- After air conditioning repair always check the system for leaks.

Review Questions

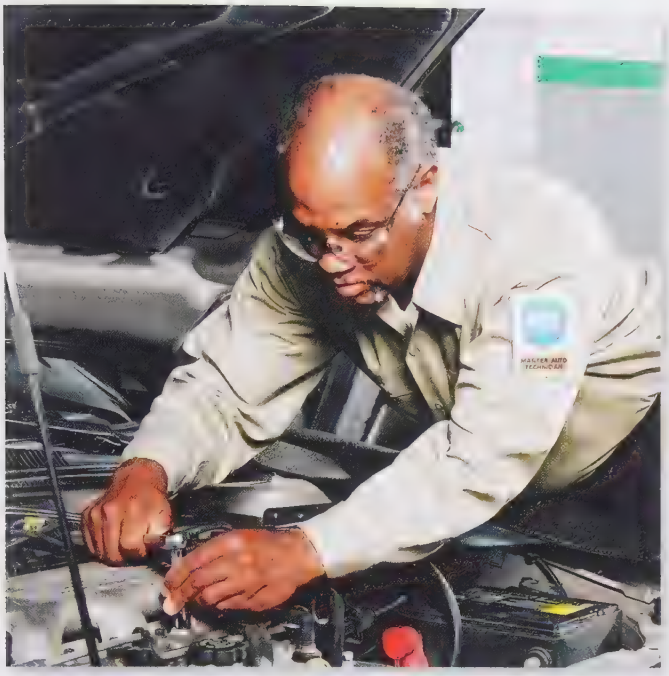
Please do not write in this textbook. Place your answer on a separate sheet of paper.

1. Explain the importance of a radiator in a vehicle's cooling system.
2. The ______ circulates coolant through the engine and radiator.
3. Explain the direction coolant may flow through a radiator.
4. A(n) ______ opens and closes, depending on engine temperature.
5. The fan clutch allows the fan to slow or stop rotation at highway speeds. True or False?
6. The ______ directs airflow from the radiator.
7. A bent pulley is detected by ______.
8. Coolant should be mixed with ______ water.
9. The heater core functions exactly like a(n) ______.
10. ______ refrigerant is no longer manufactured in the United States,
11. Can R-134a and R-12 be intentionally discharged into the atmosphere?
12. R-134a can be substituted for R-12. True or False?
13. The condenser functions like a(n) ______ to cool the refrigerant.
14. The compressor changes high-pressure gas to ______.
15. The ______ changes the refrigerant from a high-pressure gas to a high-pressure liquid.
16. What does a desiccant do?
17. The surface of the evaporator feels cold because heat is being absorbed by the refrigerant. True or False?
18. A condenser with bent fins must always be replaced. True or False?
19. ______ is used to determine what type of refrigerant is present in an air conditioning system.
20. An R-134a system has screw-on connectors. True or False?

ASE-Type Questions

1. A serpentine belt should be replaced if it has more than ______ cracks per inch.
   (A) 2
   (B) 4
   (C) 7
   (D) 10
2. A pulley wobbles as it turns. Technician A wants to replace the pulley. Technician B wants to remove and straighten the pulley. Who is right?
   (A) A only.
   (B) B only.
   (C) Both A and B.
   (D) Neither A nor B.
3. The freezing point of coolant should be ______.
   (A) –40°F (–40°C)
   (B) 0° F (–17°C)
   (C) 32° F (0°C)
   (D) 40° F (4.4°C)
4. The fan shroud is an important part of an efficient cooling system. Technician A says the fan shroud directs the airflow. Technician B says the fan shroud is typically made of plastic and is bolted to the radiator. Who is right?
   (A) A only.
   (B) B only.
   (C) Both A and B.
   (D) Neither A nor B.
5. The ratio of antifreeze to water in the coolant can be determined with a ______.
   (A) hydrometer
   (B) manometer
   (C) ratiometer
   (D) vanmeter
6. A radiator, which is below the engine, must be filled. Technician A wants to check the service manual for the right procedure. Technician B wants to open the air bleeds. Who is right?
   (A) A only.
   (B) B only.
   (C) Both A and B.
   (D) Neither A nor B.
7. An air conditioning system condenser has flattened fins but the system is fully charged. Technician A wants to replace the condenser. Technician B wants to straighten the fins. Who is right?
   (A) A only.
   (B) B only.
   (C) Both A and B.
   (D) Neither A nor B.

8. The high- and low-pressure side fittings on R-134a systems cannot be confused because the fittings are:
   (A) identical.
   (B) different sizes.
   (C) different shapes.
   (D) screws.
9. A Schrader valve has ______.
   (A) push-on connectors
   (B) screw-on connectors
   (C) bolts
   (D) screws
10. An air conditioning system has been open for two days. Technician A wants to replace the accumulator. Technician B wants to replace the receiver/drier. Who is right?
   (A) A only.
   (B) B only.
   (C) Both A and B.
   (D) Neither A nor B.
11. A refrigerant identifier has found out that an air conditioning system contains an unknown type of refrigerant. Technician A wants to remove the unknown refrigerant and store it in a separate container. Technician B wants to let the refrigerant discharge out into the atmosphere because it is not R-12. Who is right?
   (A) A only.
   (B) B only.
   (C) Both A and B.
   (D) Neither A nor B.
12. Moisture in an air conditioning system causes the formation of ______.
   (A) vapor
   (B) acid
   (C) oil
   (D) gas
13. To remove all traces of water during evacuation, the system should be held under a vacuum for at least ______ minutes.
   (A) 5
   (B) 10
   (C) 20
   (D) 30
14. Once the air conditioning system refrigerant recovery is complete, the pressure gauge should read ______ psig.
   (A) 0
   (B) 5
   (C) 10
   (D) 20
15. An air conditioning line must be replaced. Technician A wants to replace the O-rings. Technician B wants to put engine oil on the new O-rings. Who is right?
   (A) A only.
   (B) B only.
   (C) Both A and B.
   (D) Neither A nor B.
16. An electronic leak detector locates leaking refrigerant at a junction between two air conditioning lines. Technician A says an O-ring is bad. Technician B says the compressor must be replaced. Who is right?
   (A) A only.
   (B) B only.
   (C) Both A and B.
   (D) Neither A nor B.



Chapter 22

Power Train

Objectives

After studying this chapter, you will be able to:

- Name and explain the function of power train components.
- Identify damaged power train components.
- Explain how to remove and replace damaged engine and drive train components.

Technical Terms

air intake system
belts, pulleys
catalytic converter
constant velocity joint
endplay
engine cradle
evaporative emissions control system
exhaust system
fuel system
inertia switch
motor mounts
universal joints

Introduction

In a motor vehicle, the term *power train* refers to the group of components that generate power and deliver it to the road. This chapter covers power train component operation, damage, and replacement. The first section identifies engine and drive train parts, explains how these parts function, and describes the ways these parts may be damaged in a collision. The balance of the chapter deals with power train service and repair.

All motorized vehicles have an engine. The engine delivers power to the drive wheels through a transmission or transaxle, and a drive shaft or drive axles. A front-wheel-drive vehicle has a transversely mounted engine, a transaxle, and two drive axles (half shafts). A rear-wheel-drive vehicle has a longitudinally mounted engine, a transmission, a drive shaft, and a rear axle assembly.

In addition to the components mentioned above, a four-wheel-drive vehicle uses a transfer case to divide power between the front and rear wheels. In full-time four-wheel drive or all-wheel drive, all wheels are powered at all times. In part-time four-wheel drive, the transfer case only sends power to all four wheels as needed. In some part-time four-wheel-drive vehicles, the rear wheels are powered at all times and the transfer case powers the front wheels. In other part-time four-wheel-drive vehicles, the front wheels are powered at all times and the transfer case powers the rear wheels.

Engine Components

The engine generates the power required to move the vehicle. The engine burns fuel within its cylinders and converts the expanding force of the burning fuel into a rotary motion that is used to propel the vehicle. A typical automotive engine is shown in **Figure 22-1**.

Various engine components can be damaged during a collision. When the vehicle is traveling forward and collides with a solid object, the engine continues to move forward for a fraction of a second. This movement may cause the engine to impact a solid object, such as the frame. In a collision, the movement of the frame rails, or the engine itself, may damage the engine block.

For example, the oil filter and oil filter mounting area on the engine block may also be damaged by engine movement during an impact. On many vehicles, the oil filter is mounted on the engine block. Damage to the filter may cause damage to the mounting area. Check for oil leaks. If damage is suspected, remove the oil filter and check the mounting area for cracks.

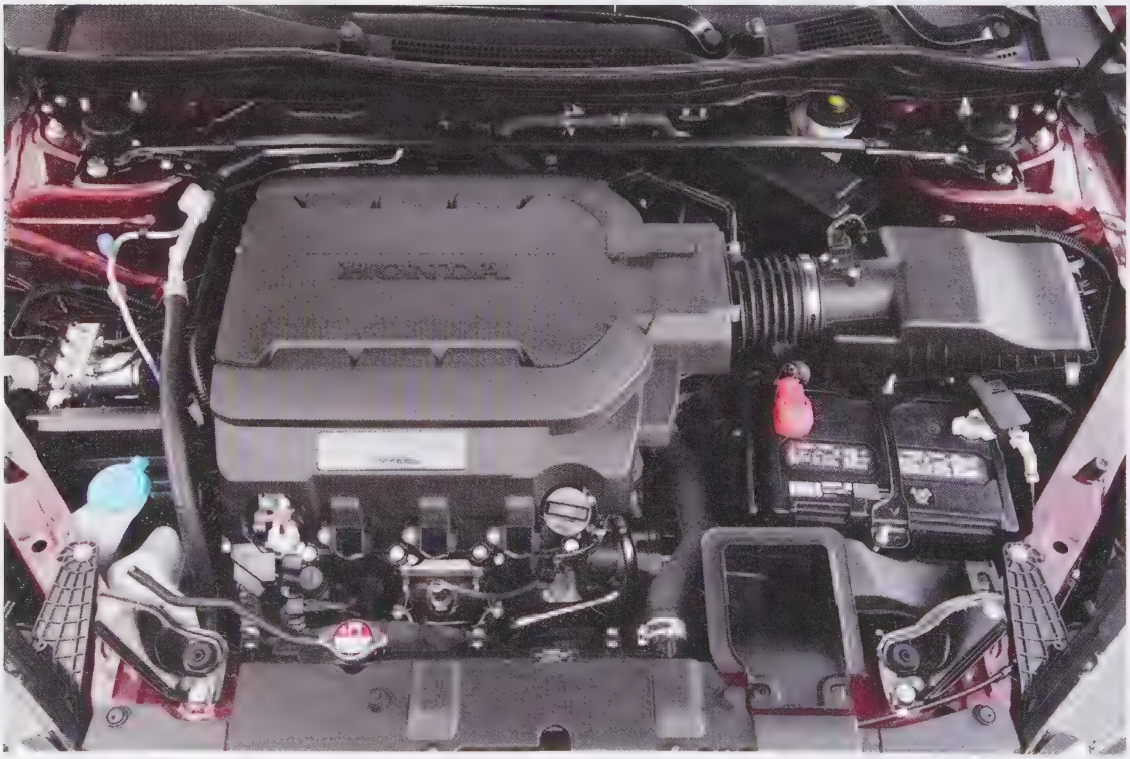


Figure 22-1. *This transversely mounted engine layout is common in front-wheel-drive vehicles.*

NOTE

A collision-damaged vehicle with engine-block damage may not be considered repairable due to the high cost of repair.

Be suspicious of engine damage on a vehicle involved in a rollover accident. An engine may continue to run after a rollover. When an engine is upside down, oil is no longer being drawn into the engine. If an engine runs without lubrication—even for a brief period—the engine may be permanently damaged. There may be no obvious signs of this type of damage. The only way to determine if damage, due to lack of lubrication, has occurred is to disassemble the engine.

Some cars are protected from this problem by an inertia switch that shuts down the engine after a rear end collision or rollover. Other types of vehicles are designed to shut down if the engine oil pressure drops below a specified value.

There are several external engine components that may be damaged in a collision. These include the air intake system components, fuel system components, emission control system components, engine pulleys, and motor mounts.

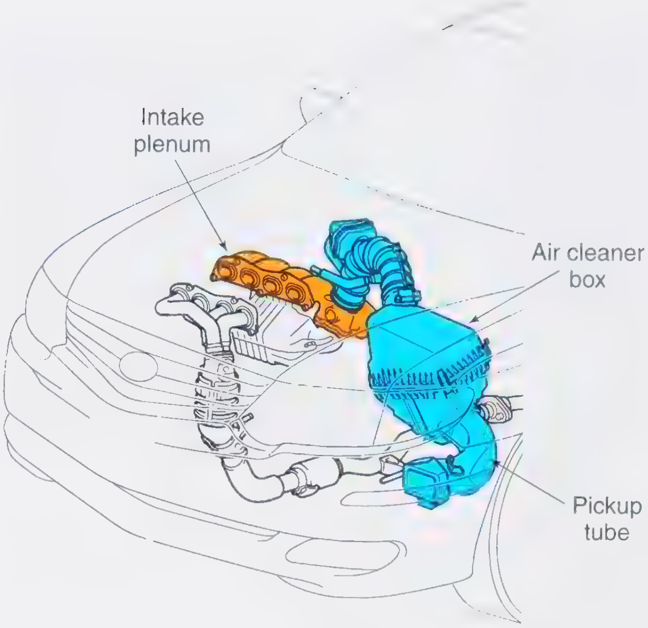


Figure 22-2. *This air intake system consists of a pickup tube, air cleaner box, and intake plenum. An impact can damage the plastic parts. (Toyota)*

Air Intake System

The ***air intake system*** brings cool outside air to the engine. The components of the air intake system are located in the engine compartment. At a minimum, the air intake system consists of plastic tubing and a plastic air cleaner box, as well as the intake plenum and manifold. See **Figure 22-2**. The intake manifold and plenum are mounted on the engine block. They are protected in most collisions.

The air cleaner box may be directly behind the radiator support. A front or side impact can damage the plastic parts. **Figure 22-3** shows a damaged air cleaner box. The assembly can be replaced or, if the damage is minor, the cracks in the plastic case can be welded. After visually inspecting for damage, shake the components to check for looseness.

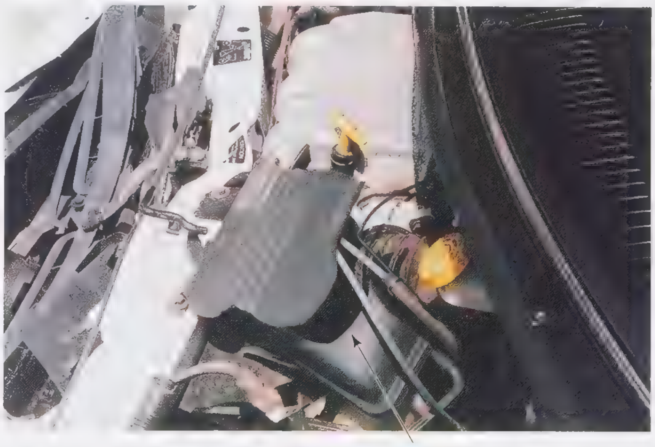


Figure 22-3. *A high front hit has damaged the air cleaner box on this minivan.*

Fuel System

The ***fuel system*** stores fuel and moves it to the engine. The fuel system in a fuel-injected gasoline engine consists of a fuel tank, fuel cap, fuel filler neck, inertia switch, fuel pump, fuel line, throttle body, fuel rail, regulator, and fuel injectors.

The fuel tank stores fuel until it is needed. The fuel cap seals the tank to prevent leaks and the evaporation of the fuel. A fuel pump draws fuel from the tank and pushes it toward the fuel injectors. Steel or rubber fuel lines connect the fuel tank to the fuel rail, which is connected to the injectors.

Fuel-injected vehicles are equipped with an ***inertia switch***, which shuts down the fuel pump in the event of a collision. This switch prevents fuel from being sprayed from the fuel system if a fuel line is damaged. To start a vehicle after the inertia switch has been tripped, the switch must be reset.

Fuel system components are sometimes damaged during a collision. For example, a side impact at the fuel cap door can damage the fuel filler neck. The fuel filler neck is a tube that directs fuel into the tank. A fuel tank can be damaged by a rear impact. Fuel lines can also be damaged. Leaking fuel or dents in the fuel tank are reliable indicators of fuel system damage. Damaged fuel system parts are generally replaced, not repaired.

Emissions Control System

Emissions control components are strategically located in places where they will not easily be damaged during a collision.

Fuel evaporating into the atmosphere causes air pollution. The ***evaporative emissions control system***, or EVAP system, prevents this type of air pollution by absorbing fuel vapors and routing them back to the engine to be burned. The components of a typical EVAP system are shown in **Figure 22-4**.

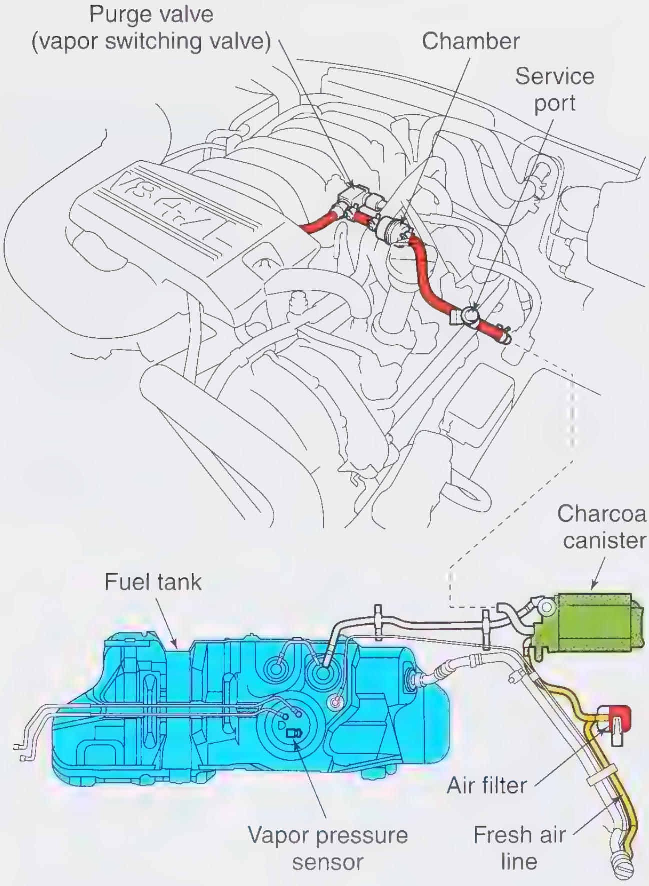


Figure 22-4. *The evaporative emissions control system, or EVAP system, prevents the evaporation of fuel into the atmosphere by absorbing fuel vapors and routing them back to the engine to be burned. (Toyota)*

The EVAP system may be located in an area that can be damaged during a collision. The damage may be similar to that found on the air intake system. The plastic parts or hoses may be cracked or torn. Shake the parts to check for looseness. Look carefully for cracks. Replace the damaged parts.

WORKING GREEN

Evaporative emissions, which typically come from fuel that escapes unburned from storage tanks and fuel lines, are comprised of volatile organic compounds. They contribute significantly to the nation's ground-level ozone problem, causing harm to human health and public welfare.

A separate emission control system acts on engine exhaust gases. Untreated exhaust gases contain air pollutants such as hydrocarbons, carbon monoxide, and oxides of nitrogen. An air injection system, which pumps air into the exhaust manifold, reduces hydrocarbon and carbon monoxide emissions by promoting further burning of the gases. Many air injection systems use an air pump to introduce air into the exhaust manifold. This air pump is powered by a belt and will be found at the front of the engine, among the alternator, power steering pump, and air conditioning compressor. Due to its location at the front of the engine, an air pump may be damaged by a front impact (longitudinally mounted engine) or side impact (transversely mounted engine). The tubes and hoses may also be damaged. Check for bends or cracks in the tubes and cracks in the hoses.

NOTE

The remaining exhaust gas emission control components, the oxygen sensor and the catalytic converter, are covered as part of the exhaust system.

Engine Pulleys

Belts and ***pulleys*** are used to transfer motion from the engine's crankshaft to the power steering pump, air conditioner compressor, and alternator. A side impact may move a frame rail enough to damage a pulley on a front-wheel-drive engine. A hard front impact on a rear-wheel-drive vehicle may damage pulleys. Pulley damage is easy to see on a running engine. Any pulley that wobbles is damaged. Never attempt to repair a damaged pulley! **Figure 22-5** shows pulley damage.

Mounts for the drive belt tensioner may be broken off the block. A replacement bracket may be available that does not use these mounts. If this replacement

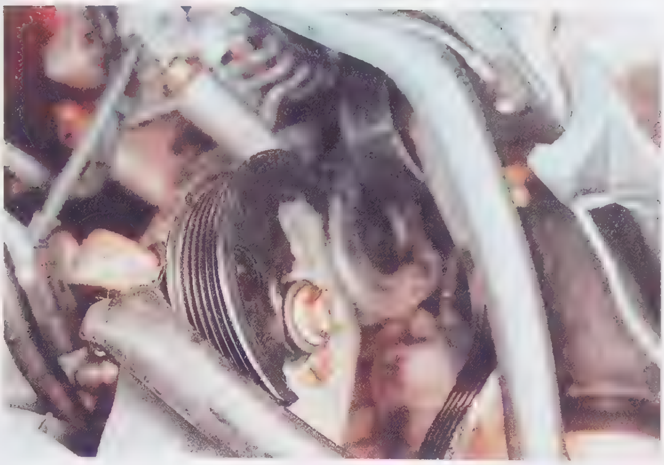


Figure 22-5. *Here is a broken pulley. Breakage is less common than bending.*

bracket is not available, the engine block will need to be replaced. This expense may cause the vehicle to be declared a total loss.

Motor Mounts

Motor mounts connect the engine to the vehicle's frame or unibody. Motor mounts contain a rubber section or are filled with thick liquid to isolate engine vibration from the vehicle. Motor mounts can be damaged in a collision. When a vehicle's forward motion is abruptly stopped, the engine continues to move forward for a fraction of a second. This force may bend or break a motor mount or break the bracket the motor is bolted to. Damage to motor mounts is shown in **Figure 22-6**.

To check for a damaged motor mount, start the engine and apply the brakes. Shift the vehicle into *Drive* and watch for the engine to move. If the engine moves up at one end in *Drive* and lifts up at the other end when the vehicle is shifted into *Reverse*, a motor mount may be broken. Damaged motor mounts should be replaced.

Exhaust System

The ***exhaust system*** channels waste combustion gases from the engine to the rear of the vehicle. The parts of a typical exhaust system are shown in **Figure 22-7**. The exhaust manifold collects the exhaust gases from the engine and routes them to the exhaust pipe. The exhaust gases move through the exhaust pipe to the catalytic converter and eventually to the muffler. The ***catalytic converter*** burns up polluting exhaust gases.

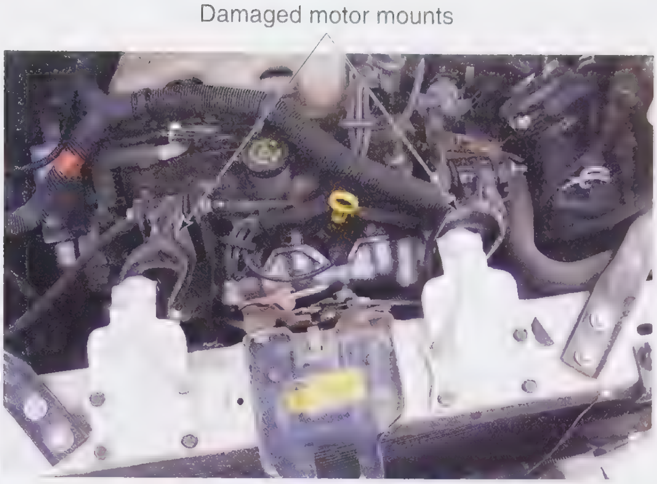


Figure 22-6. *A side impact on the left front of this minivan moved the radiator support to the right and bent both upper motor mounts.*

The muffler reduces engine noise, and a resonator is used in some systems to further reduce engine sounds. The tailpipe moves the gases from the muffler or resonator to the rear of the vehicle.

The oxygen sensors gauge the combustion air/fuel ratio by measuring the amount of oxygen in the exhaust gas. The oxygen sensor sends electrical information in the form of voltage to the engine electronic control module to help maximize fuel economy and minimize air pollution.

A heat shield is a metal shell that wraps around the catalytic converter or other exhaust system components. The upper portion of the heat shield protects the body or engine components from the heat produced by the exhaust system during engine operation. The lower portion of the heat shield prevents objects under the vehicle from touching the hot surface of the catalytic converter and causing a fire. A heat shield is made from aluminum alloy. Convolutions formed in the heat shield provide strength and increase surface area for improved heat dissipation. The upper portion of a heat shield may be bolted to the underside of the vehicle or to the engine block.

To prevent harmful waste gases, such as carbon monoxide, from entering the vehicle, the entire exhaust system must be airtight. The pipes may be joined by welding, with muffler clamps, or with bolted flanges.

Any part of the exhaust system can be damaged in a collision. The exhaust manifold can be cracked if the engine moves during an impact. The catalytic converter can be crushed if the vehicle leaves the roadway and lands on its underside. The muffler can be dented in a side hit and the thin-wall exhaust pipes can collapse in a rear hit. Most exhaust system

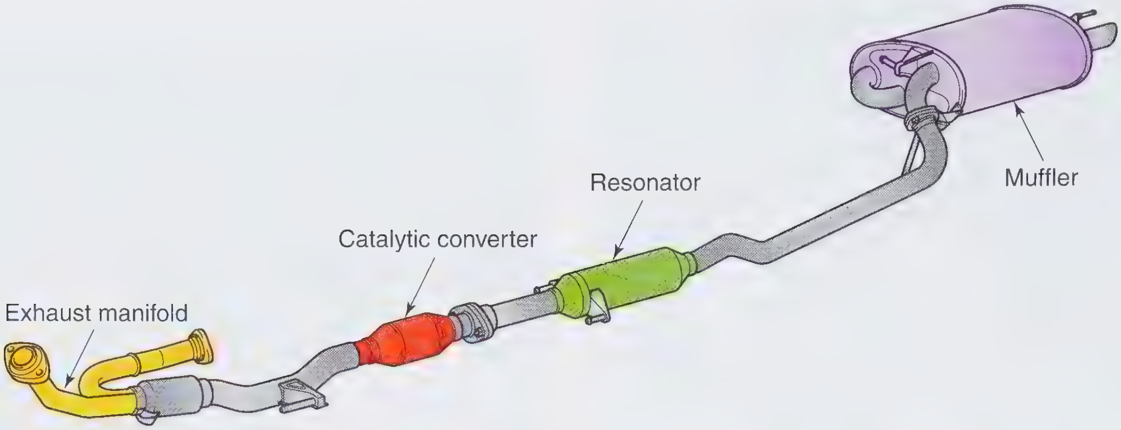


Figure 22-7. *The exhaust system starts near the front of the vehicle and stretches almost to the rear of the vehicle. (Toyota)*

damage can be spotted during a close inspection of the underside of the vehicle. Look for cracks, dents, or bends. Damaged exhaust system parts are replaced, rather than repaired.

Drive Train Components

The drive train conveys power produced by the engine to the drive wheels. On rear-wheel-drive vehicles, the engine power drives the rear wheels only. On a front-wheel-drive vehicle, only the front wheels are driven. On four- and all-wheel-drive vehicles, all the wheels are driven.

Rear-Wheel-Drive Components

In a rear-wheel-drive vehicle, the rear wheels power the vehicle. The engine is longitudinally mounted (engine crankshaft is parallel with the vehicle's centerline) in a rear-wheel-drive vehicle. The transmission is mounted behind the engine, under the passenger compartment. **Figure 22-8** shows typical rear-wheel-drive components.

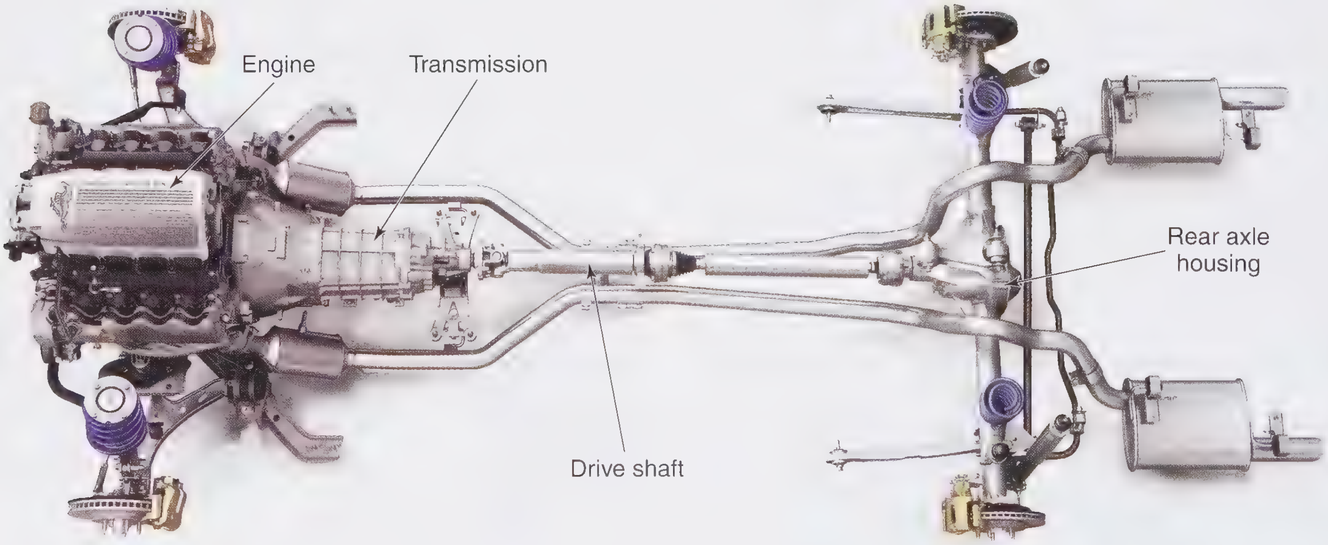


Figure 22-8. *The major components of a rear-wheel-drive system include the engine, transmission, drive shaft, and rear axle housing.*

The major components of a rear-wheel-drive system include the transmission, drive shaft, and rear axle housing.

Transmissions can be manual or automatic. A clutch is used in a manual transmission to engage and disengage power from the engine to the transmission. Manual transmissions may use a hydraulic clutch, with a clutch master cylinder, clutch slave cylinder, and clutch line, or a mechanical clutch and clutch linkage. See **Figures 22-9 and 22-10**. A clutch master cylinder converts the driver's foot pressure into hydraulic pressure to actuate other devices such as a slave cylinder. A clutch slave cylinder moves the throwout bearing to engage or disengage the clutch disc from the flywheel. The clutch line is metal tubing through which flows hydraulic fluid. Clutch linkage is a group of mechanical or hydraulic components that transmit and multiply the force created by the driver stepping on the clutch pedal.

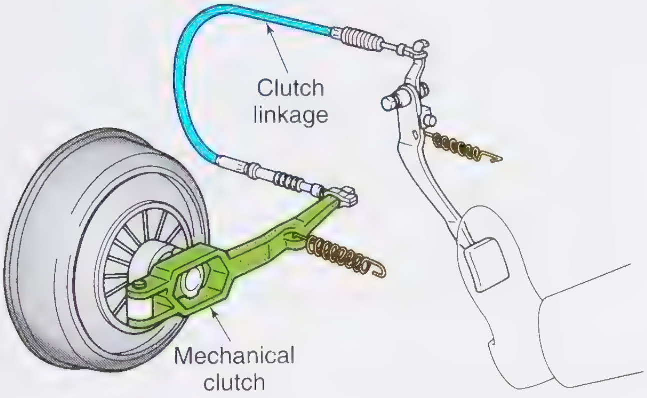


Figure 22-9. *Mechanical clutch and clutch linkage. (Toyota)*

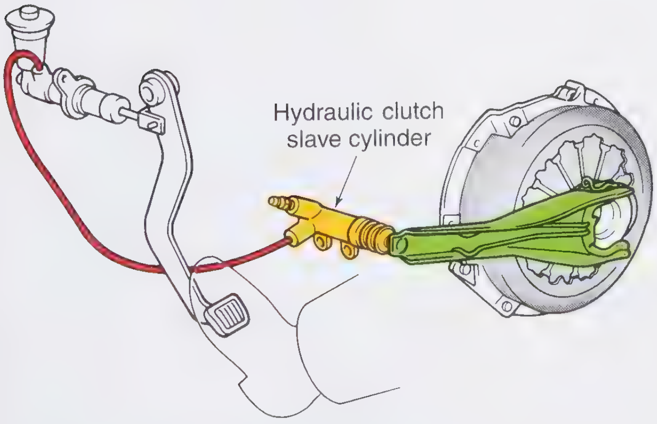


Figure 22-10. *A clutch slave cylinder moves the throwout bearing to engage or disengage the clutch disc from the flywheel. (Toyota)*

Figure 22-11 shows an automatic transmission bolted to an engine. The automatic transmission is found in 85% of vehicles on the road today. Torque multiplication is one of the reasons for its popularity. Torque converters can double the torque to the transmission. This type of transmission does not shift gears the way manual transmissions do. Instead, an automatic transmission uses hydraulic fluid to move bands and clutches to engage sets of planetary gears.

A transmission's case can be cracked in a collision. Leaking fluid may be an indication of a cracked case. However, the transmission is located so deep inside of the vehicle that damage is uncommon. Momentum may damage the transmission mounts, as well as the shift or clutch linkage. Inspect mounts for misalignment. Shifting of the transmission mounts can cause the linkage to bind. If the vehicle is hard to shift, check the linkage for damage. It may be bent or rubbing against another object. Realignment of the transmission should correct the problem if the linkage is not bent. If the pan on an automatic transmission is dented, check for internal damage.

The output shaft of the transmission is connected to the vehicle's drive shaft. As the drive shaft spins, power is conveyed to the rear axles. The drive shaft must be balanced to prevent vibration. The drive shaft contains ***universal joints***, or U-joints. These joints allow the drive shaft to rotate while the suspension moves up and down. See **Figure 22-12**. A hard impact on a rear wheel may force the rear axle housing to move far enough to damage the rear U-joint. Also, the drive shaft may be dented by an under-the-vehicle impact. A dented drive shaft may be out of balance. A broken U-joint is obvious; the drive shaft is no longer connected to the rear axle assembly. Some weakened universal joints may cause a noticeable vibration. A worn or damaged U-joint will be loose. As the drive shaft turns, this looseness causes excessive vibration and noise. Damaged U-joints should not be repaired. Instead, replace the damaged part.

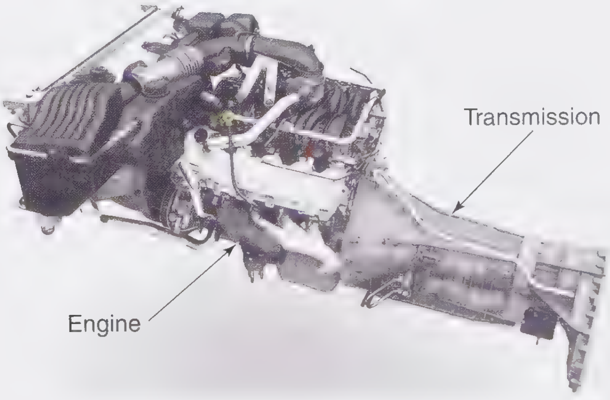


Figure 22-11. *An automatic transmission bolts to the engine block. The case can be cracked in a collision.*

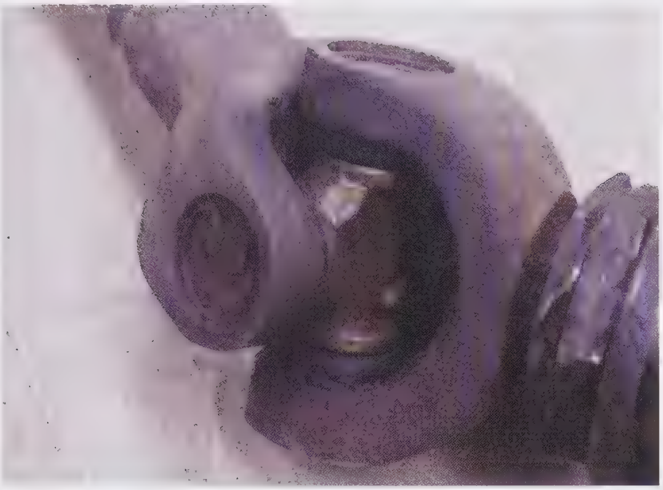


Figure 22-12. *U-joints allow the driveshaft to rotate while the suspension moves up and down.*

A rear axle assembly is shown in **Figure 22-13**. The parts of a rear axle assembly include the rear axle housing, differential gears, and drive axles. The differential gears, which are located inside the housing, allow the two rear wheels to rotate at different speeds as the vehicle is turned. The rear axle housing contains lubricating oil. Independent rear suspensions (IRS) were once reserved for sports cars such as the Corvette, but are now increasingly used in less exotic vehicles. The advantages of an IRS suspension include a 50% reduction in unsprung weight, no drive shaft torque, elimination of wheel hop, and more trunk space. The axles of an IRS have U-joints like a drive shaft.

An impact on a rear wheel can bend a drive axle. Check for a bent drive axle as shown in **Figure 22-14**. If the brake drum does not wobble when compared to the pointer, the drive axle is straight. The axle housing can also be bent by an impact to the rear wheel. Find a reference point at the center of the rear axle housing and take comparative measurements between this point and each brake drum. Any difference in measurements indicates a problem. A fluid leak also indicates a problem, such as a bent axle, torn seal, or cracked case. Replace any damaged components.

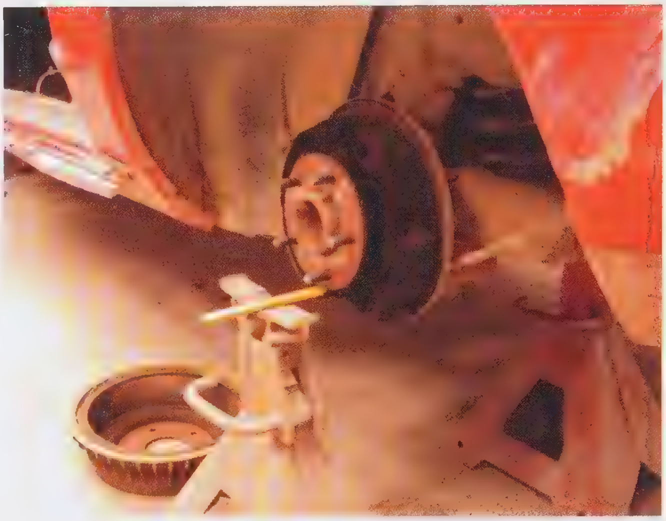


Figure 22-14. *The pencil on the jack stand serves as a reference point when checking the rotation of the rear axle for wobble.*

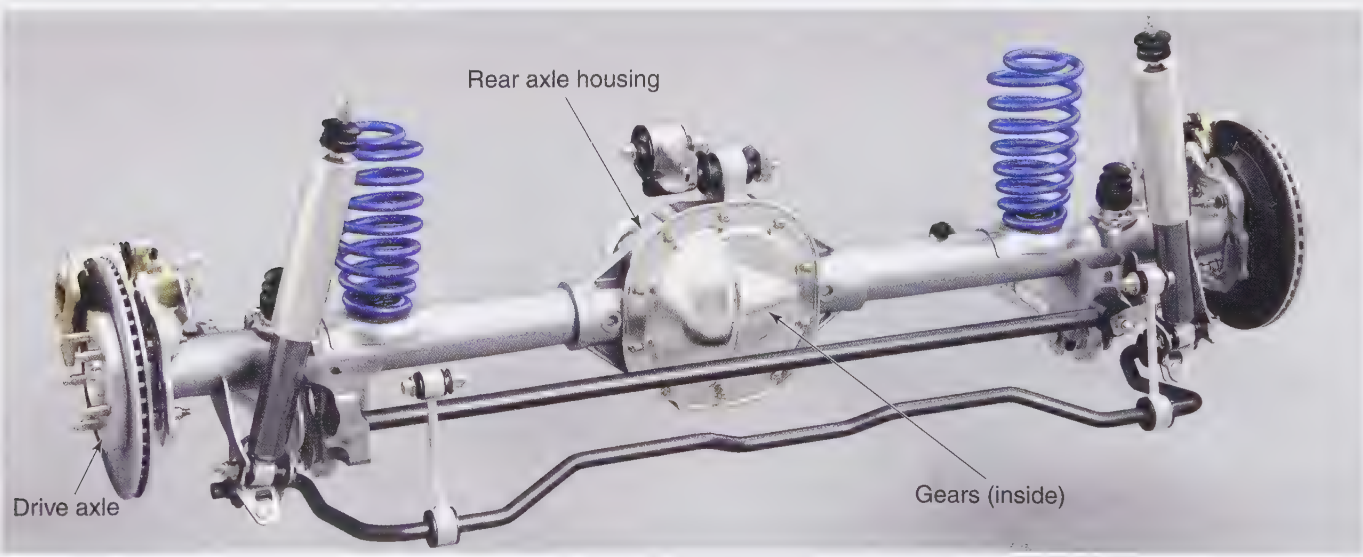


Figure 22-13. *The rear axle assembly includes the housing, gears, and axles.*

Front-Wheel-Drive Components

In a front-wheel-drive vehicle, the front wheels not only steer, but also power the vehicle. The rear wheels do not power the vehicle; they are freewheeling. In a front-wheel-drive vehicle, the considerable weight of the engine is over the drive wheels, providing good traction. In these vehicles, the engine is transversely mounted in the engine compartment. See **Figure 22-15**. The major components of a front-wheel-drive system include the transaxle and the drive axles.

The transaxle transfers engine power to the drive axles and front wheels. It also allows the front wheels to rotate at different speeds during turns. The transaxle does the same job as the transmission and differential in a rear-wheel-drive vehicle.

Collision damage to either a manual or an automatic transaxle is usually confined to the case or the linkage. However, internal damage is possible if the bottom end of the transaxle slams down on a hard object. A broken case may leak oil. Cracks may be discovered after careful inspection. Bent linkage may be present if the transaxle cannot be shifted or if shifting is difficult. **Figure 22-16** shows a damaged transaxle.

Drive Axles

The drive axles, or half shafts, connect the transaxle to the front wheels. One of the drive axles is longer than the other. A ***constant velocity joint***, or CV joint, is found at each end of the drive axle. The CV joints transfer rotation through various angles without variations in drive axle speed. The CV joints allow the axle to move with the wheel as the wheel turns or moves up and down. The CV joint at the transaxle end of the drive axle is called the inner CV joint, while the CV joint at the wheel end of the drive axle is called the outer CV joint. The inner CV joint must move in and out to compensate for changes in axle length as the wheels move up and down over an uneven road.

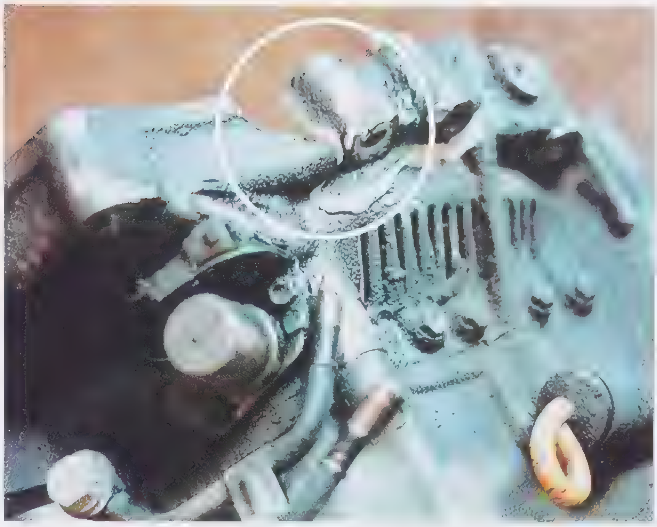


Figure 22-16. *This transaxle has a cracked case. Inspect linkage for damage.*

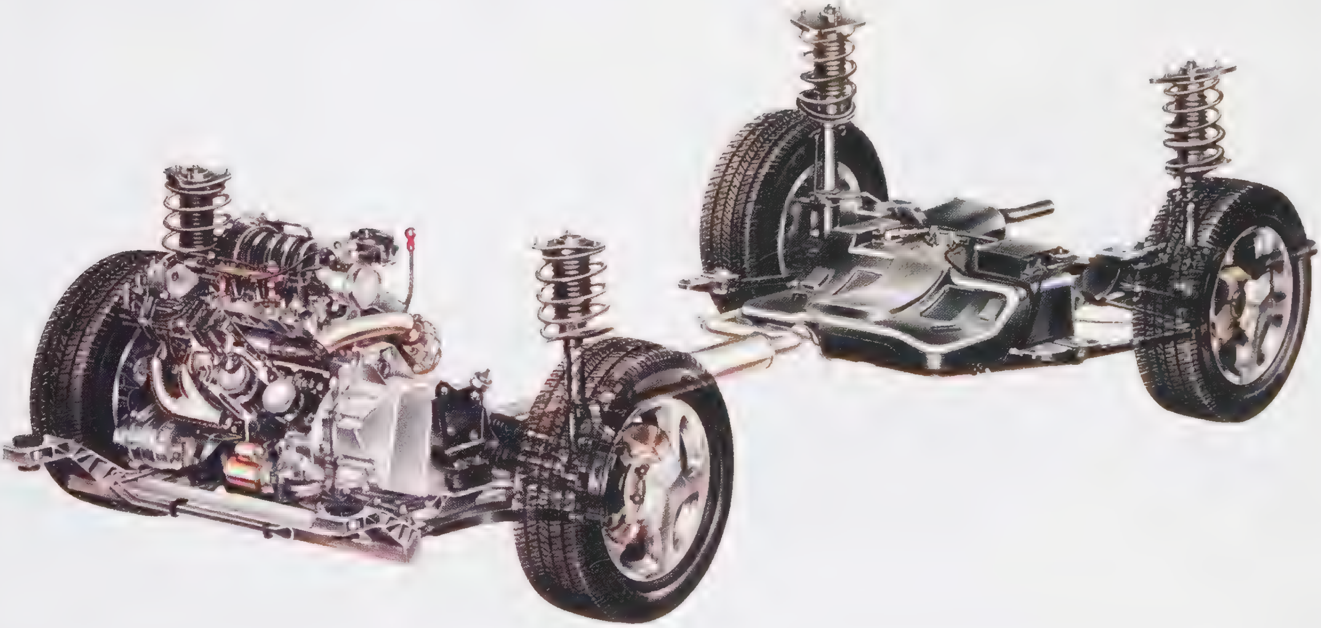


Figure 22-15. *In a front-wheel-drive vehicle, the considerable weight of the engine is over the drive wheels, providing good traction.*

Therefore, the two joints have different designs. The major parts of the CV joint include the boot, bearing cage, bearing race, and bearings.

An impact on a front wheel can damage the CV joints and drive axle. A hard impact may pull the drive axle out of the transaxle, as shown in **Figure 22-17**. Check the axle for leaking grease at the boot, misalignment, a torn boot, or bends. A damaged CV joint can be replaced, or the entire drive axle, including the CV joints, can be replaced.

Engine Cradle

Front-wheel-drive vehicles may be equipped with an ***engine cradle***, which supports the engine, transaxle, front suspension, and rack-and-pinion assembly. See **Figure 22-18**. The engine cradle is attached to the unibody with bolts.

An engine cradle can be damaged by an impact on the unibody or the front suspension. Minor bends can be straightened, but if the suspension mounting points are damaged, the cradle should be replaced. **Figure 22-19** shows a damaged engine cradle.

Four-Wheel-Drive and All-Wheel-Drive Components

Many vehicles are equipped with four-wheel drive. The drive train parts of a four-wheel-drive vehicle are shown in **Figure 22-20**. Four-wheel-drive pickup trucks and many SUVs have longitudinally mounted engines. A drive shaft at the rear of the transmission powers the rear wheels through the rear differential and axles.

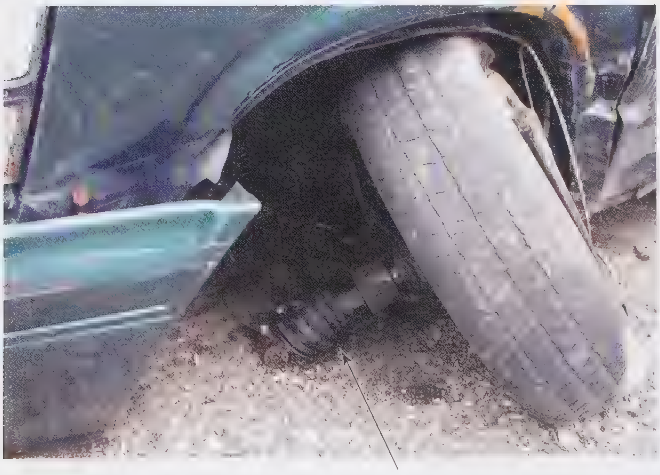


Figure 22-17. *A front impact forced the wheel back, damaging the fender and breaking the lower control arm, tie rod, and inner CV joint.*

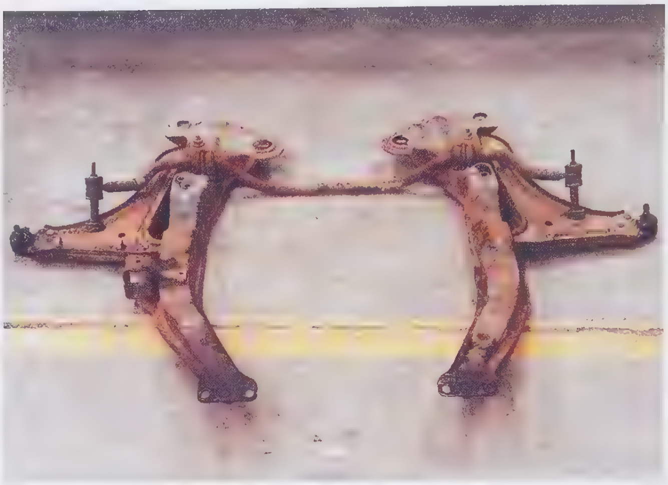


Figure 22-18. *An engine cradle can be damaged by an impact on the unibody or on the front suspension.*

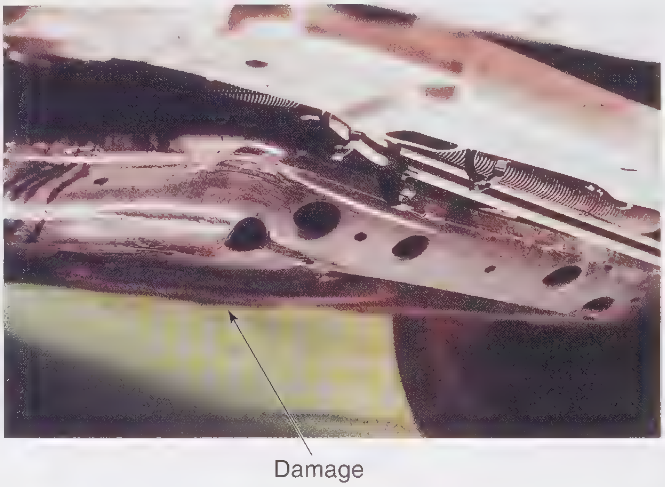


Figure 22-19. *This engine cradle is bent. Minor bends can be straightened unless mounting points are damaged.*

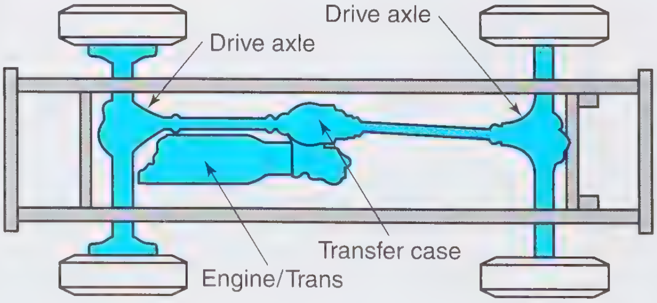


Figure 22-20. *In a four-wheel-drive vehicle, the transfer case powers the front differential via the front drive shaft.*

A transfer case, mounted either behind or to the side of the transmission, powers the front wheels through a drive shaft, a front differential, and axles. The front axles have constant velocity joints to allow them to turn while driving the wheels. The transfer case may have high and low ranges. The low range allows the engine to run at a speed that produces maximum torque to plow through snow or mud.

The front hubs on four-wheel-drive vehicles may be locking hubs. Manual locking hubs must be locked and unlocked by the driver. When the four-wheel drive is desired, the driver must get out of the vehicle and turn a selector switch located on the hub. See **Figure 22-21**. The majority of locking hubs are automatic. Automatic locking hubs do not require the driver leave the vehicle for switching.

In an all-wheel-drive vehicle, also known as a full-time four-wheel-drive vehicle, all four wheels are powered at all times. In an all-wheel-drive vehicle equipped with a transversely mounted engine, power is conveyed from the engine to the transaxle and transfer case. The transfer case powers the front wheels through the front differential. The front differential allows the front wheels to rotate at different speeds when the vehicle is turning a corner. The transfer case also powers the rear drive shaft. The drive shaft conveys power to the rear wheels through the rear differential. The rear differential allows the rear wheels to rotate at different speeds when the vehicle is turning.

Damage to four-wheel-drive parts can occur from an impact on a wheel. Damage can also occur from momentum if the vehicle slams into an immovable object or by the transfer of impact force through a full frame. The mounting tabs of a front differential can be broken by a side impact at the front of the vehicle. The frame may move sideways with enough force to break the mounting tabs. **Figure 22-22** shows damaged four-wheel-drive parts. When checking for damage, look for fluid leaks, cracks in the transfer case, broken mounts, or bent components.

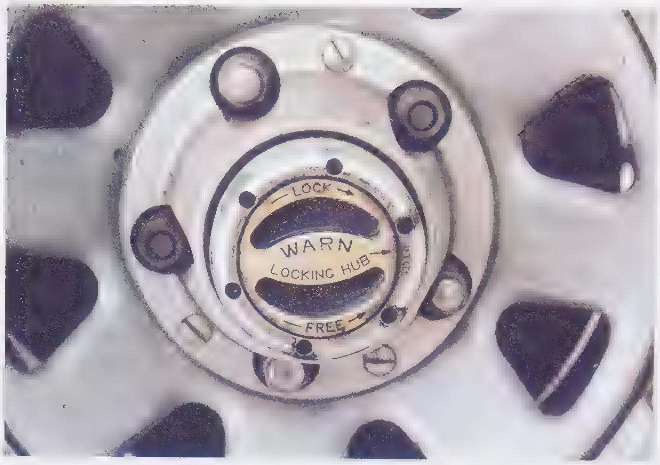


Figure 22-21. *This is manual locking hub on a four-wheel-drive pickup truck.*

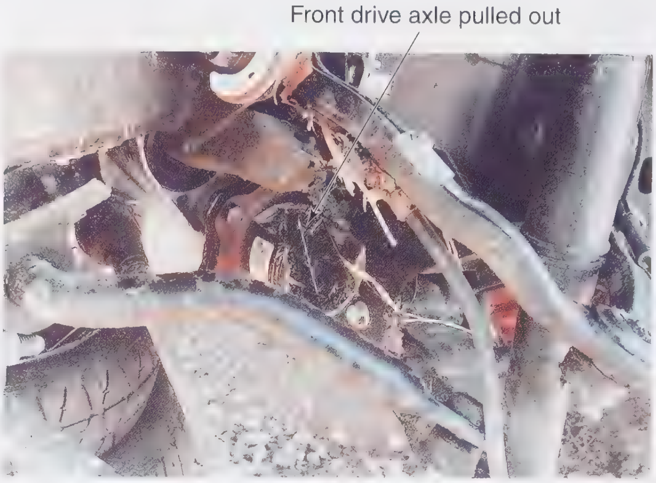


Figure 22-22. *This four-wheel-drive pickup truck has sustained damage to the left drive axle and front axle housing.*

Power Train Service and Repair

Body repair technicians should be able to recognize power train damage and perform component replacement. A side impact near the back of a rear-wheel-drive car may crack the rear axle housing. An abrupt stop, caused by a front impact, may release the inertia of the engine and transaxle to bend the motor mounts. Running off the road and hitting a concrete culvert with a wheel may break the front differential, axle shaft, and hub of a four-wheel-drive pickup truck. A vehicle exhibiting power train damage has been hit hard. Often, hard-hit vehicles are not repaired because the cost of repair exceeds the value of the vehicle.

Checking Fluids

All collision repair technicians must know how to check power train fluids. Fluids are essential for vehicle operation. Collision repair technicians should also know how to lift an engine, replace a transaxle, and remove a gas tank.

The engine, transaxle, transmission, transfer case, and axle assemblies all require oil for lubrication. These parts will be ruined if they are operated with little or no lubricating oil. Each part requires a different type of lubricant. Check the manufacturer's recommendations for the proper type of fluid. The vehicle must be level when fluids are checked.

Running off the road may damage the oil pan or oil filter on an engine. An engine equipped with a remote oil filter, for easier access when changing the oil, may have the oil filter located to a place where it can be damaged in a front end collision. If oil is leaking from the vehicle, find the source of the leak. After the leaking component is repaired or replaced, add the recommended amount of oil and check the oil level.

The engine should not be running. Oil is circulated throughout the engine during operation. When the engine is shut off, the oil drips down into the oil pan. The engine should be shut off for at least 10 minutes before checking the oil to give an accurate oil level reading. If the oil level on the dipstick is below "Add," pour oil into the engine through the engine oil fill hole.

CAUTION

Overfilling an oil pan beyond the recommended level may be hazardous to the health of an engine. Overfilling by a small amount is not a problem, but too much oil—more than a quart—may result in catastrophic engine damage. When the connecting rods and crankshaft rotate through the oil in the pan, they whip the oil into an air-bubble-filled foam. Foamy oil does not efficiently move through the oil pump and oil passages in the engine block. The result is under-lubrication and bearing failure.

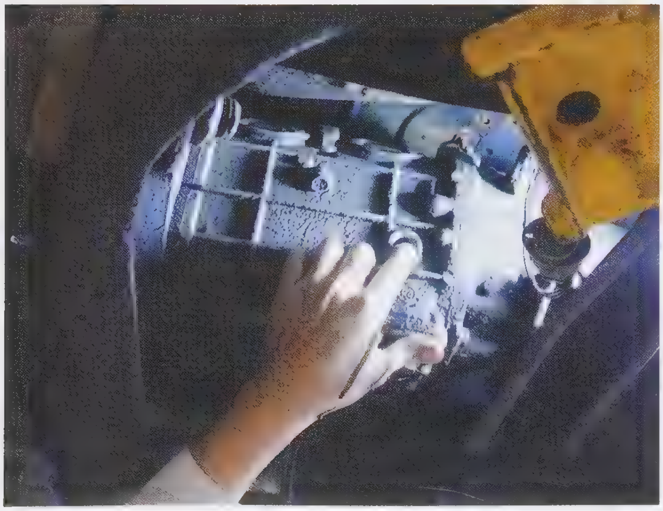


Figure 22-23. *Check the fluid level in a manual transmission by feeling the fluid level with your finger.*

After replacing the transmission, fill it with the recommended lubricant. After filling, the fluid level of the lubricant should be checked.

Figure 22-23 shows how to check the fluid level in a manual transmission or transaxle. Remove the fill plug with a square-drive ratchet. Place a finger inside of the hole. If fluid is level with the hole, the level is correct. If not, add fluid.

A front or side impact may crack a transaxle's housing. A transaxle with a cracked housing must be replaced. An under-the-vehicle impact, caused by running off the road, may damage an axle housing. A side or rear impact may break the rear axle housing, requiring replacement. After replacing the rear axle housing, the differential should be filled with the recommended fluid. After filling, the fluid levels should be checked to verify a proper repair. To check the fluid level in an axle housing, remove the fill plug. Insert your finger into the fill hole. If your finger can detect fluid level with the fill hole, the level is correct. If not, add fluid through the fill hole.

NOTE

Some automatic transmissions and transaxles do not have dipsticks. When servicing these units, refer to the manufacturer's instruction for checking fluid levels.

Fuel and Emission Control System Service

Fuel, intake, and emission control system service may be required in collision repair. Some parts of these fuel systems, such as the charcoal canister or air cleaner box, may be located in areas susceptible to collision damage.

Fuel-injected vehicles have pressurized fuel lines. To prevent accidental release of fuel, follow the manufacturer's recommendations on how to depressurize the system. For example, you may need to disable the fuel pump and run the engine until it is out of fuel. After the fuel line is depressurized, the line can be disconnected. To remove the line, push down on the fitting's locking tabs while pulling the fitting apart. To reconnect, push the ends of the fitting together until the locking tabs snap into place.

If the fuel tank must be replaced, drain the gas from the damaged tank into a "gas buggy." This portable storage device minimizes the possibility of a fire from spilled gasoline. Once the tank is drained, remove the filler neck and plug the hole in the tank. In some designs, the tank and filler neck are one unit. Then, remove and plug the gas line.

Gas tanks are usually held in place with straps. With the tank safely supported, unbolt the straps. Some vehicles have an electric fuel pump in the tank. A special tool may be required to open the tank. Install the new tank by reversing the removal procedure.

Damage to EVAP system parts, such as a cracked charcoal canister, is corrected by replacing the parts. Broken or torn hoses should also be replaced.

Plastic welding can repair minor damage to plastic tubing and the air cleaner box in the intake system. If the damage to the air cleaner box is extensive enough to expose the air filter, the air cleaner box should be replaced, not repaired.

Exhaust System Service

The exhaust system, especially the catalytic converter, is hot during engine operation. Allow the system to cool before working on it. A catalytic converter has flanges at the front and rear for bolting it to flanges on the exhaust pipes. Remove the nuts from the bolts or studs at the flanges. Because the catalytic converter is in line with the rest of the exhaust system components, it may be wedged in so tightly that it will not drop out when the flanges are unbolted. If this happens, an exhaust pipe to the front or rear should also be unbolted to allow enough play to remove the catalytic converter. The heat shield may be bolted or welded to the catalytic converter, or it may be bolted to the underbody or engine block of the vehicle. To protect the vehicle, be sure that the heat shield is in place when the new catalytic converter is installed.

An oxygen sensor is replaced by disconnecting the wiring harness from the sensor. Then, using a line wrench, an open-end wrench, or an oxygen sensor socket, loosen and remove the sensor. Do not contaminate or touch the sensing area on the replacement oxygen sensor. Bolt or thread the replacement oxygen sensor in place and tighten to the specified torque value. Finally, reconnect the wiring harness.

Exhaust system service generally involves replacing damaged components. One end of the exhaust pipe is bolted to the exhaust manifold. The nuts holding the exhaust pipe flange may be rusted on. Heat the nuts with a torch or vibrate the nuts with an air chisel before attempting removal.

The tailpipe may be attached to the muffler with a muffler clamp. After loosening the nuts on the clamp, slide the muffler and the pipe apart. When exhaust pipes are joined, one pipe is slightly larger in diameter than the other. The smaller pipe fits inside of the larger pipe.

Some exhaust hangers cannot be removed. If this is the case, cut the hanger with a cut-off tool. To install a new part, insert the hanger through the rubber grommet. See **Figure 22-24**.

Drive Belt and Pulley Service

Drive belts power the accessories on an engine. Some vehicles are equipped with a belt tensioner. When the tensioner is released, the belt can be removed. **Figure 22-25** shows how this self-tensioner maintains the correct amount of pressure to always keep the belt tight. As the belt stretches and loosens with age, the tensioner compensates and keeps it tight. Routing of the belt is critical. The new belt must be replaced in exactly the same position as the old one.

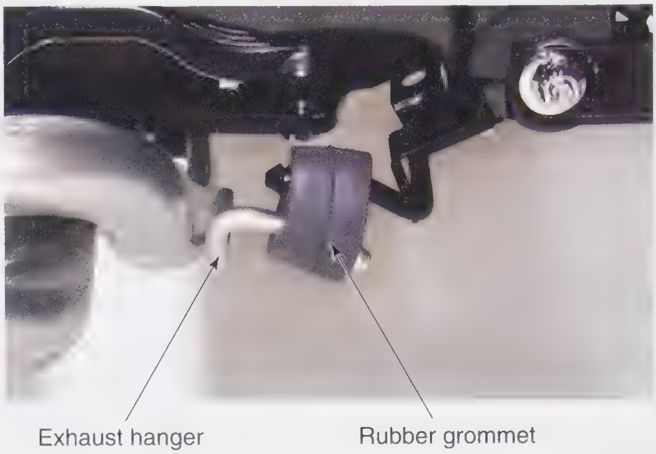


Figure 22-24. *To install a new exhaust system component, insert the hanger through the rubber grommet.*

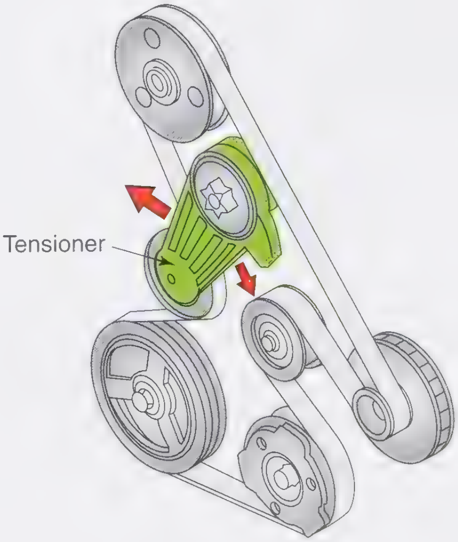


Figure 22-25. *Some vehicles are equipped with a belt tensioner. When the tensioner is released, the belt can be removed.*

If the vehicle is not equipped with a tensioner, a component, such as the alternator, must be loosened to allow for enough slack to remove the old belt and install a new one. Once the new belt is on, the loosened component is repositioned to a point where the belt is tight. See the service manual for the recommended amount of deflection in the belt.

Always replace a damaged pulley; do not try to straighten a bent pulley. Pulleys are strong. A collision with enough force to bend a pulley may also damage the component behind the pulley. Always check the part a damaged pulley is attached to for additional damage.

Check manufacturer recommendations for pulley replacement procedures. Some pulleys are bolted in place. Removal and installation of the bolts requires that the pulley be held in place while the bolts are turned. A strap can be wrapped around the pulley to hold it in place. Other types of pulleys are pressed onto a shaft; there are no bolts. Removal of a pressed-in-place pulley requires a puller. Some pulleys require a specially designed puller, while other pulleys can be removed with a universal puller. Installation of a new pressed-in-place pulley requires a hydraulic press. The hydraulic press applies even force to push the pulley in place. Other types of pressed-in-place pulleys may require a special installation tool. This type of installation tool reverses the action of a puller.

Adjusting Linkages

Linkages are used for clutch operation, transaxle or transmission gear selection, and throttle operation. Linkages may be made up of a rod or a cable. Due to damage or misalignment, linkages may need to be adjusted. Also, during drive train removal, the linkages must be removed. When reinstalled, the linkages will need to be adjusted. Adjustment and removal procedures vary from one vehicle to another, so consult a service manual before servicing the shift linkage.

Removing and Installing a Motor Mount

To replace a motor mount, the engine must be supported and the motor mount must be unbolted from the engine and frame. The engine can be supported by an engine hoist or jack. The motor mount may be on a bracket. These brackets are often bent when a motor mount is damaged. Before installing a new motor mount, remove the damaged bracket and replace it with a new one.

When installing a motor mount, check for proper alignment as the drive train is repositioned. Torque all fasteners to the manufacturer's recommended specifications. When the engine is secured to the motor mount, remove the support.

WARNING

An unsecured engine can lurch when started and cause injuries.

Removing and Installing a Front-Wheel-Drive Engine and Transaxle Assembly

In some cases, damage is so severe that it will be necessary to remove a vehicle's engine or replace an engine cradle. Repair or replacement of front unirails may also require power train removal. With the power train removed there is easy access to the unirails and shock towers. Although the operation requires that many components be disconnected, the procedure is straightforward.

CAUTION

When attaching a lifting fixture to an engine, be sure to determine the correct attachment points. In some cases, engine bolts can be used to secure lifting tabs. The recommended points of attachment are listed in the vehicle service manual.

Removing an Engine and Transaxle Assembly from Below

Power train can be removed from below the vehicle if a lift is available. The power train is heavy, so be careful. The procedure is:

1. Position the vehicle on a lift.
2. Disconnect the battery.
3. Drain and disconnect the radiator and heater hoses.
4. Recover the refrigerant from the A/C system. Disconnect and plug the A/C lines. (There are instances when the compressor can be removed from the engine and moved off to the side. This eliminates the need to open the AC system.)
5. Disconnect the exhaust pipe from the engine.
6. Disconnect the shift linkage from the transaxle (automatic transmission); disconnect the clutch linkage (manual transmission).
7. Disconnect the brake lines from the brake calipers and cap the brake lines.
8. Be sure the fuel system is depressurized before disconnecting the fuel line.
9. Locate and disconnect all electrical wire connectors between the engine and the vehicle. Mark each connector to simplify reinstallation. There may be a major electrical connection at the cowl, which may be hidden inside of the cowl.

10. Disconnect the steering linkage if the rack and pinion will stay with the cradle. If the rack and pinion is mounted on the cowl, disconnect the tie rod ends. Disconnect power steering lines.
11. Position an appropriate stand or cart under the engine cradle to support the drive train. A wheeled cart will allow the drive train to be moved.
12. Remove the strut nuts at the shock tower.
13. Remove the cradle bolts.
14. Raise the vehicle so the power train remains on the stand while the vehicle rises.
15. While slowly raising the vehicle, look for missed connections and binding.

Figure 22-26 shows what a removed front-wheel-drive cradle and power train look like. To install the drive train, reverse the removal procedure.

Removing and Installing an Engine/Transaxle Assembly from Above

A front-wheel-drive vehicle power train can be removed from above with the aid of an engine hoist. The power train is heavy and awkward to lift in this manner. Working space is limited. To remove a power train from above the vehicle:

1. Disconnect the battery.
2. Remove the hood.
3. Drain the radiator and disconnect the radiator and heater hoses.
4. Recover the refrigerant from the A/C system. Disconnect and plug the A/C lines. (There are instances when the compressor can be unbolted from the engine and moved off to the side. This eliminates the need to open the A/C system.)
5. Disconnect the air tubing from the engine and remove the air cleaner.
6. Disconnect the exhaust pipe from the engine.
7. Disconnect the shift linkage from the transaxle.
8. Verify that the fuel system is depressurized then disconnect the fuel line and throttle cable.
9. Remove the drive axles from the transaxle. If the vehicle is a manual transaxle, disconnect the clutch linkage.
10. Drain the power steering fluid and disconnect the power steering lines from the pump. (There are instances when the power steering pump can be unbolted from the engine and moved off to the side. This eliminates the need to open the system.)
11. Remove the serpentine belt.
12. If necessary, remove the alternator, A/C compressor, power steering pump, air injection pump, and all pulleys from the front of the engine. An engine/transaxle can be removed with these components on the engine.
13. Locate and disconnect all electrical connectors between the engine and the vehicle. Mark each connector to simplify reinstallation.
14. Position an engine hoist at the front of the vehicle. Attach a chain to the engine lifting hooks. Raise the hoist to take out any slack in the hoist chain.
15. Unbolt the motor and transaxle mounts.
16. Raise the engine with the hoist to clear the engine compartment. Be alert for any attached wires, lines, or hoses.
17. Roll the engine hoist away from the vehicle and lower the engine.

Figure 22-27 shows the removal of a front-wheel-drive power train from above. To reinstall the power train, reverse the removal procedure.

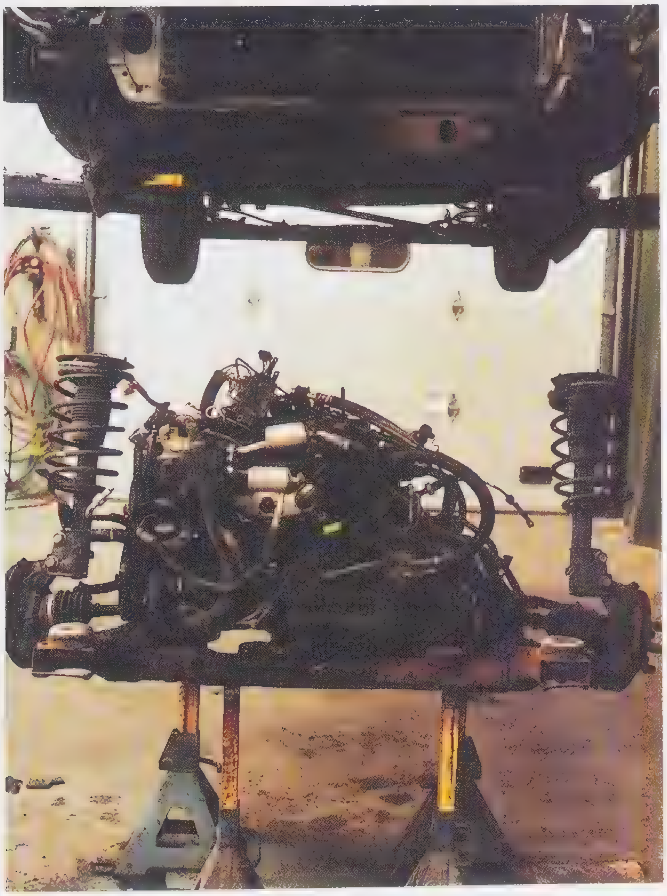


Figure 22-26. *The drive train has been removed by disconnecting the necessary components and raising the vehicle.*

CAUTION

Unequal distribution of the engine weight may cause the engine to twist or sag at one end. Lower the engine into the engine compartment and reposition the hoist hook on the lifting tab chain if this happens. The power train may need to be pushed or shifted to clear the cowl.

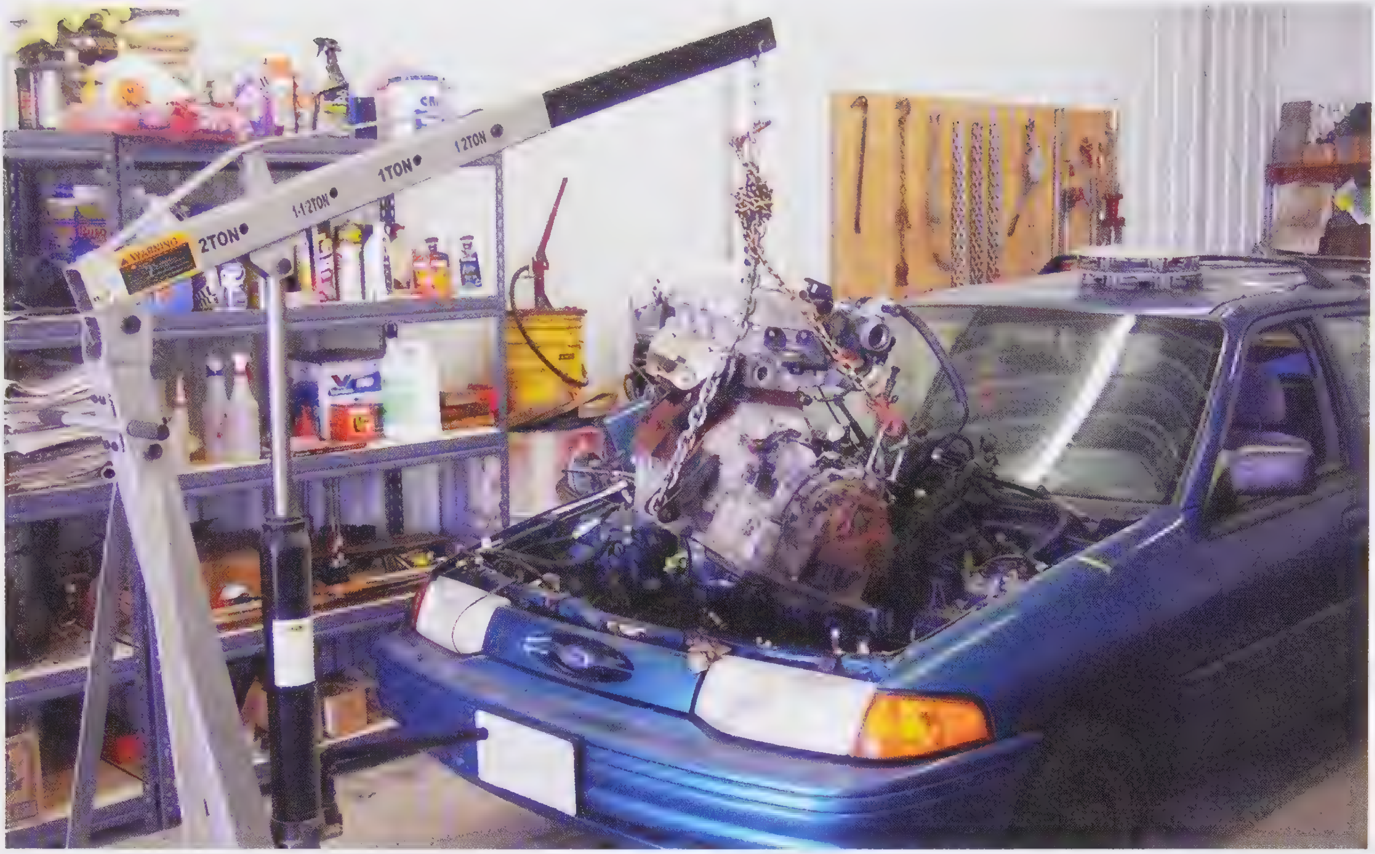


Figure 22-27. *The engine and transaxle were removed from this front-wheel-drive vehicle by raising the engine and transaxle with a hoist.*

Transaxle Removal

A damaged transaxle can be removed without removing the engine. Check the service manual for the recommended method. The plan is to disconnect the transaxle and drop it down. Position the vehicle on a lift. Remove the half shafts, shift linkage and on manual transaxles, clutch linkage. Support the engine because once the transaxle is out, the engine will droop. Place a jack under the transaxle; then unbolt the transaxle and the engine mounts from the engine. Raise the vehicle. On automatic transaxles, install a strap to keep the torque converter in place. A cracked transaxle case can be replaced by a specialty shop or the body shop can install a used or rebuilt transaxle. Reverse the removal steps to install the new unit.

Removing and Installing an Engine Cradle

To remove the engine cradle, the drive train and vehicle must be supported. The drive train can be supported with an engine lift. The vehicle can be supported with jack stands placed under the rocker panels. With the drive train supported, disconnect the suspension and the steering system, if needed. Disconnect the motor mounts so the drive train is free of the engine cradle. Place a floor jack under the cradle and unbolt the engine cradle from the unibody. The cradle can then be lowered with the jack. To install a new cradle, reverse the procedure.

Removing and Installing a Half Shaft

Half shafts that are damaged during a collision must be replaced. To remove a half shaft:

1. Raise and support the vehicle using a lift or a floor jack and jack stands.
2. Remove the wheel and tire assembly on the axle to be serviced.
3. Remove the brake caliper and rotor.
4. Loosen and remove the hub nut. The hub nut may be a single-use nut. If so, it must be replaced.

NOTE

In some cases, the nut is held in place with a cotter pin, which must be removed before the nut can be loosened. Do not reuse cotter pins.

---

5. To remove the outer stub shaft from the steering knuckle, tap on the end of the shaft with a plastic hammer. In some cases, a special puller may be needed to remove the shaft from the hub.
6. In most cases, the steering knuckle must be disconnected from the lower ball joint to allow for half shaft removal. Remove the bolt securing the steering knuckle to the lower ball joint. This bolt may be a single-use fastener. Then, remove the steering knuckle from lower ball joint. It may be necessary to tap or pry the steering knuckle from the ball joint.
7. Remove the inner stub shaft from the transaxle. In many cases, it is necessary to use a puller or pry bar to remove the shaft from the transaxle. When using a puller, pull only on the inner CV joint. In some cases, the inner end of the shaft is bolted to the transaxle flange. To remove these shafts, simply remove the bolts and pull the half shaft from the vehicle. As the inner stub shaft slides out of the transaxle, push against the steering knuckle for additional clearance.

CAUTION

After removing the axle, do not turn the opposite wheel! Turning the opposite wheel with one half-shaft removed will cause the side gears inside the transaxle to rotate. Without the support of the removed half shaft, the side gears will become misaligned.

Installing a Half Shaft

1. If the original half shaft will be reused, install a new circlip (if required) on the inner stub shaft end. A new half shaft should come with a new circlip already installed.
2. Align the splines on the shaft with the splines on the transaxle side gear.
3. Slide the inner stub shaft into the transaxle. There should be a distinct "clunking" sound as the circlip seats. Install the bolts if the half shaft is held in place with bolts.
4. Align the splines on the half shaft with the splines on the steering knuckle. It may be necessary to slightly turn the outer CV joint to get the proper alignment.
5. Slide the half shaft into the steering knuckle. Pull on the knuckle to set it in place.
6. Attach the lower ball joint to the steering knuckle. Install the bolt and torque to specifications.
7. Install the hub nut and torque it to the specified value. Install a new cotter pin, if used.
8. Install the rotor and caliper.
9. Install the wheel and tire.

Removing and Installing a Rear-Wheel-Drive Power Train (Longitudinal Engine)

In some cases, it will be necessary to remove a vehicle's engine and transmission. In most cases, the engine is removed from above, and the transmission is removed from below. However, the transmission can be removed with the engine from above.

Engine or drive train removal requires that electrical connections be removed. Look for a junction block where two connectors meet. Some connectors are held together with tabs. Some large junction blocks are held together with a bolt.

Removing and Installing a Longitudinal Engine

The first task in removing the engine is to determine where the lifting fixture must be attached. In some cases, engine bolts can be used to hold the tabs on the engine chain. See **Figure 22-28**. The location of these bolts is listed in the vehicle service manual. After selecting the proper location, install the tabs and bolts.

1. Disconnect the battery.
2. Remove the hood.

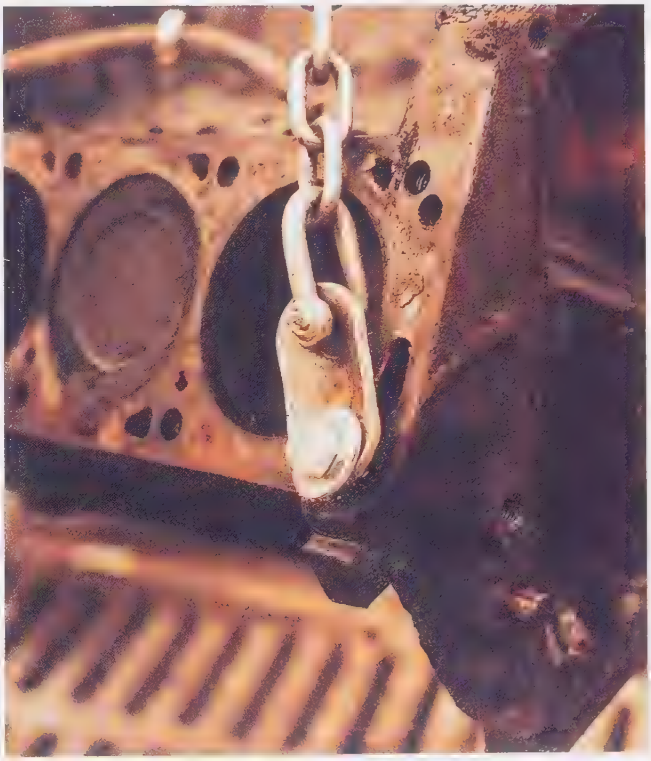


Figure 22-28. *The lifting tab is bolted to a threaded hole in the engine block.*

3. Drain the radiator and disconnect the radiator and heater hoses.
4. Recover the refrigerant from the A/C system. Disconnect and plug the A/C lines.
5. Disconnect the air tubing from the engine and remove the air cleaner.
6. Disconnect the exhaust pipe from the engine.
7. Verify that the fuel system is depressurized, then disconnect the fuel line and throttle cable.
8. Drain the power steering fluid and disconnect the power steering lines from the pump. In some cases, it may be better to unbolt and move the power steering pump instead of draining fluids and disconnecting lines.
9. Remove the starter.
10. Unbolt the transmission or bell housing from the engine block.
11. Locate and disconnect all electrical wire connectors between the engine and the vehicle. Mark each connector to simplify reinstallation.
12. Position an engine hoist at the front of the vehicle. Attach a chain to the engine lifting hooks. Raise the hoist to take out any slack in the hoist chain.
13. Unbolt the motor mounts.
14. Raise the engine slightly with the hoist. Check to see if any additional wires, hoses, or lines must be disconnected.
15. Pull the engine forward to separate it from the transmission. Separate the engine block and transmission with a crowbar if necessary.
16. Raise the engine out of the engine compartment with the hoist. Roll the engine hoist away from the vehicle.

Reverse the removal steps to reinstall the engine.

CAUTION

For safety reasons, lower the engine as soon as it clears the vehicle. Rolling an engine hoist with a heavy engine raised up high is a tipping hazard.

Removing and Installing a Transmission

A collision-damaged transmission may have a cracked case. Most body shops replace a damaged transmission with a used or rebuilt transmission. Transmission replacement is easier with a lift. Obtain the manufacturer instructions for transmission removal and installation and follow them. The following steps are general instructions for removing a damaged transmission:

1. Disconnect the battery.
2. Position the vehicle on a lift.
3. Drain the transmission fluid.
4. Disconnect the drive shaft from the transmission.
5. Disconnect the shift linkage, speedometer cable (if used), electrical connection on the transmission, and coolant lines.
6. Position a jack to support the transmission and secure the transmission to it.
7. Unbolt the transmission from the engine block.
8. Raise the vehicle with a lift.
9. Pull the transmission out from under the vehicle.

Reverse the removal steps to install a replacement transmission.

Removing and Installing a Drive Shaft

The drive shaft is bolted to the rear axle housing companion flange. At the transmission, the splined drive shaft yoke slides into the transmission. U-joints at each end of the drive shaft allow the drive shaft to rotate as the suspension moves up and down.

The drive shaft is removed by unbolting at the companion flange. Marks should be scribed on the flange for alignment on reinstallation. Once the drive shaft is unbolted at the companion flange, the drive shaft can be pulled out of the transmission. Plug the end of the transmission to prevent leaks.

Note the alignment marks made during disassembly. Begin drive shaft installation by sliding the yolk into the transmission. Make sure the drive shaft matches up with the alignment marks. Bolt the companion flange together.

A special gauge is used to measure the angle at which the drive shaft meets the rear axle housing. If this angle is out of specification, wedges can be driven in between the springs and the rear axle spring mounts. If the wedges are inserted from the front they will tilt the front of the axle housing up. If the wedges are inserted from the rear they will tilt the front of the axle housing down. Install wedges as needed to achieve the proper angle.

U-joints are subject to wear and may be damaged in a collision. Refer to the service manual for details on removal and installation of U-joints.

Removing and Installing a Rear Axle

By necessity, the rear axle housing is strong and heavy. A motor vehicle accident can damage this robust component and technicians are called on to replace damaged rear axle components. Consult the service manual for the proper rear axle removal and installation procedure. The rear wheel should be removed as well as the brake drum or rotor. In a flanged end axle, remove the retaining nuts and pull out the axle with a slide hammer. In some cases, the axle is held in place with a C-lock or a bolt. To remove this type of axle, first drain the oil from the rear axle housing. Next, remove the bolts holding the rear axle housing cover. The C-lock or bolt is at the end of the axle. Pull off the C-lock or remove the bolt. The axle can then be pulled out of the housing. See **Figure 22-29.**

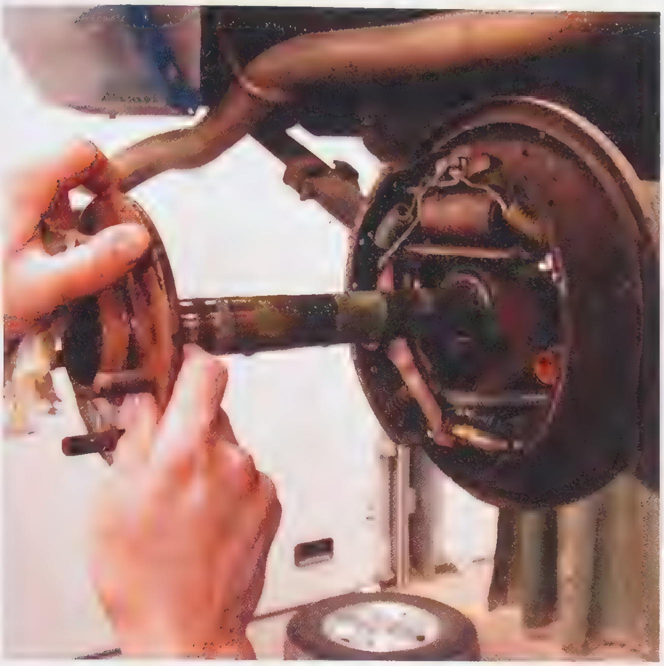


Figure 22-29. *Removing the C-lock from the rear differential allows the axle to slide out of the rear axle housing.*

If the axle is broken, use a magnet to help remove the broken part(s). Look for debris in the axle housing.

Before installing a replacement axle, make sure the axle is clean. New gaskets or rear wheel bearings may be required. Slide the axle into the axle housing. Install the C-lock or bolt. Replace the cover and pour in fresh lubricating fluid.

Endplay in the axle may need to be adjusted. ***Endplay*** is a measurement of how far the axle can be pulled out and pushed in after installation. Excessive endplay must be adjusted.

Removing and Installing a Rear Axle Housing

An impact on a rear wheel can bend a drive axle. If the collision is severe that axle housing can be bent as well. The rear axle housing is bolted to either the rear springs or shock absorbers. In independent rear suspensions, the housing is bolted to the frame. Check the service manual for the recommended procedure. First, remove the drive shaft, parking brake cables, and brake lines. Place a floor jack under the center of the housing. Unbolt the springs from the shackles. Lower the jack and remove the spring/housing assembly from under the vehicle. The U-bolt nuts can be removed to separate the springs from the housing. These procedures are for a leaf spring system, but the procedures for rear axle housings with coil springs are similar. Always refer to the service manual for guidance as spring removal can be dangerous if not done correctly.

To install a replacement housing, start by installing new U-bolts. Bolt the springs in place and load the assembly onto the floor jack. Raise the assembly up to a point where the spring eyes align with the spring shackles. Install the shackle bolts. Then, reconnect the brake lines, the parking brake cables, and drive shaft.

Four-Wheel-Drive and All-Wheel-Drive Component Service

Four-wheel-drive components may need to be removed and repaired or replaced in a body shop operation. A front or side hit may damage four-wheel-drive components, or a four-wheel-drive vehicle may run over a big rock and sustain damage underneath. Additionally, undamaged four-wheel-drive components may need to be removed for access to damage during the repair process.

The removal and installation procedures of a front drive shaft and front axle housing are similar to the procedures described for rear drive shaft and rear axle housing installation. The instructions for front half shafts are similar to the procedures for front-wheel-drive half shafts. Find and follow the vehicle manufacturer's instructions. To remove and replace a front differential, disconnect the battery, block the wheels so the vehicle cannot move, disconnect the front drive shaft and half shafts, place a floor jack to support the front differential and unbolt the front differential from the mounts. Lower the front differential with the floor jack and roll it out from underneath the vehicle. Reverse the removal procedure to install the new front differential. Four-wheel-drive hub replacement may require the removal of snap rings. Check the manufacturer's recommendations for specific instructions.

A transfer case takes power from the transmission to turn output shafts in the case to rotate the front and rear drive shafts. Transfer case removal and installation is difficult because they are extremely heavy. This is not a job for one person. Use a transmission jack to lift the case into position. Once it is lined up, bolt and torque the transfer case to the transmission bell housing while making sure the output shaft splines slide into place. Hook up the drive shaft and shift linkage, fill with fluid, and connect the front and rear drive shafts to the case with U-joints. The final step is to connect the speedometer.

Some manufacturers use transmission fluid in their transfer cases; others use a gear oil specifically blended for the transfer case. For this reason, it is always wise to refer to the manufacturer's recommendations.

Summary

- Vehicles may have a front-wheel, rear-wheel, or four-wheel-drive system.
- The drive train powers the drive wheels.
- Drive train damage can occur from an impact on a wheel, on the underbody, or on the engine compartment.
- Leaking fluid is a symptom of drive train damage to the engine, transmission, transaxle, transfer case, or rear axle housing.
- A front-wheel drive train can be removed as a unit by disconnecting and raising the vehicle.
- Manufacturers have specific recommendations for drive train service. Consult a manual before making repairs.
- Damaged drive train components are usually replaced instead of repaired.
- Components of the air intake and emission control systems can be damaged in a collision.
- Pulley damage is easy to see on a running engine.
- Any part of the exhaust system can be damaged in a collision, including the exhaust manifolds.
- Body repair technicians should be able to recognize power train damage and perform component replacement.
- Linkages are used for clutch operation, transaxle or transmission gear selection, and throttle operation.
- Engines and transaxles can be removed from above or from below.
- U-joints are subject to wear and may be damaged in a collision.

Review Questions

Please do not write in this textbook. Place your answer on a separate sheet of paper.

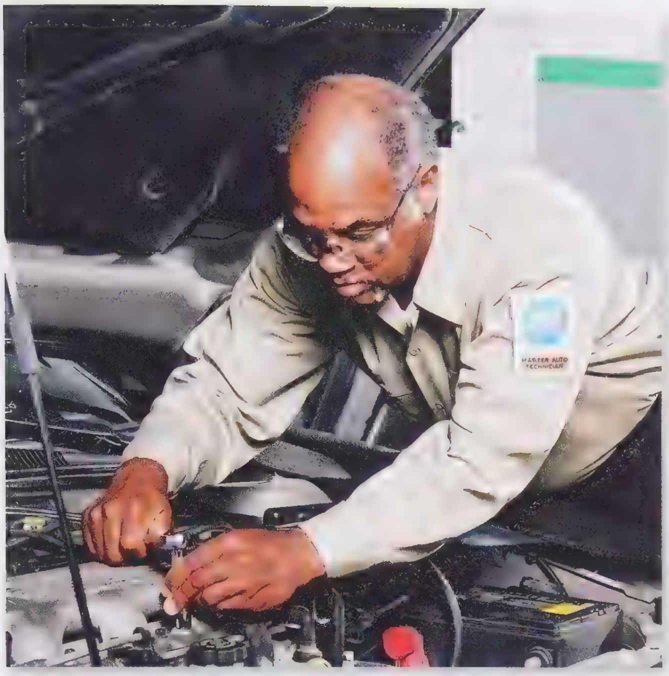
1. The ______ converts the reciprocating motion of pistons to rotary motion.
2. When a vehicle collides with a solid object, the engine continues to move forward for a fraction of a second. This violent movement may damage motor mounts, frame rails, and even the engine block. True or False?
3. If the engine on a rolled-over vehicle continues to run for several minutes, the engine will ______.
4. Explain the function of an inertia switch.
5. A(n) ______ burns up polluting exhaust gases.
6. A side impact may move a frame rail enough to damage a pulley on a front-wheel-drive engine. Any pulley that ______ is damaged.
7. A damaged pulley can be repaired. True or False?
8. Explain how to check for a broken motor mount.
9. On a front-wheel-drive vehicle, the engine is mounted ______.
10. Explain the function of a transaxle.
11. The major parts of the CV joint include the boot, ______ cage, ______ race, and the ______.
12. The CV joint at the transaxle end of the drive axle is called the ______ CV joint.
13. An engine cradle suspension mounting point is damaged during a collision. The engine cradle should be ______.
14. To check for damage on a four-wheel-drive vehicle, the technician should look for fluid leaks, cracks in the transfer case, broken mounts, and bent components. True or False?
15. The transmission case should be filled with fluid until the fluid is ______ with the fill hole.
16. Explain the function of a U-joint.
17. Explain how to check for a bent rear axle.
18. A four-wheel-drive system that can be shifted on and off as needed is a full-time four-wheel-drive system. True or False?
19. If the angle where the drive shaft meets the rear axle is out of specification, ______ can be driven in between the springs and the rear axle spring mounts to achieve the proper angle.

ASE-Type Questions

1. A collision repair technician should suspect engine damage on any vehicle involved in a rollover accident. When a vehicle is upside down, ______ is no longer being drawn into the engine.
   (A) air
   (B) oil
   (C) fuel
   (D) hydrocarbons
2. These external engine components may be damaged in a collision EXCEPT:
   (A) air intake system.
   (B) engine pulleys.
   (C) motor mounts.
   (D) engine block.
3. When a vehicle's forward motion is abruptly stopped, the engine continues to move forward for a fraction of a second. Technician A says the force can break a motor mount. Technician B says that the force can even brake the bracket the motor engine is bolted to. Who is right?
   (A) A only.
   (B) B only.
   (C) Both A and B.
   (D) Neither A nor B.

4. The exhaust system removes combustion gasses. Technician A says any part of an exhaust system can be damaged in a collision. Technician B says exhaust gasses pass through the catalytic converter before entering the muffler. Who is right?
   (A) A only.
   (B) B only.
   (C) Both A and B.
   (D) Neither A nor B.
5. The following are all major components of a rear-wheel-drive system EXCEPT:
   (A) transmission.
   (B) inertia switch.
   (C) drive shaft.
   (D) rear axle housing.
6. Momentum damage caused by the sudden deceleration of a collision may harm the transmission mounts. Technician A says inspect the transmission mounts. Technician B says check the shift/clutch linkage. Who is right?
   (A) A only.
   (B) B only.
   (C) Both A and B.
   (D) Neither A nor B.
7. A constant velocity joint, or CV joint, is found at the end of the drive axle. Technician A says the CV joint allows the axle to move with the wheels. Technician B says that an impact on a front wheel can damage the CV joints and drive axle. Who is right?
   (A) A only.
   (B) B only.
   (C) Both A and B.
   (D) Neither A nor B.
8. Which of the following tools is used to remove the inner CV joint from the transaxle?
   (A) Torch.
   (B) Wrench.
   (C) Hacksaw.
   (D) Pry bar.
9. A pressurized fuel line needs to be disconnected. Technician A wants to depressurize the system. Technician B wants to remove a clip to separate the connection. Who is right?
   (A) A only.
   (B) B only.
   (C) Both A and B.
   (D) Neither A nor B.
10. Which of the following is the greatest contamination factor in a CV joint?
    (A) Water.
    (B) Grease.
    (C) Grit.
    (D) Oil.
11. To protect the vehicle, be sure that the ______ is in place when a new catalytic converter is installed.
    (A) exhaust manifold
    (B) heat shield
    (C) spur gear
    (D) engine mount
12. An engine should be lifted by ______.
    (A) the exhaust manifold
    (B) bolt-on tabs
    (C) the intake manifold
    (D) the exhaust pipe
13. Which of the following is *not* part of the power train removal?
    (A) Disconnect the brake lines.
    (B) Disconnect the fuel lines.
    (C) Disconnect the distributor.
    (D) Disconnect the exhaust pipe.
14. A transaxle is to be removed. Technician A says a damaged transaxle can be removed without removing the engine from the vehicle. Technician B says the engine must be supported once the transaxle is out or the engine will droop. Who is right?
    (A) A only.
    (B) B only.
    (C) Both A and B.
    (D) Neither A nor B.
15. All of the following are part of a rear axle housing removal EXCEPT:
    (A) drive shaft removal.
    (B) gas line removal.
    (C) brake line removal.
    (D) parking brake cable removal.
16. Both half shafts need to be replaced on a vehicle. Technician A wants to remove and replace one side and then remove and replace the other side. Technician B wants to pull out both half shafts at the same time. Who is right?
    (A) A only.
    (B) B only.
    (C) Both A and B.
    (D) Neither A nor B.
17. Endplay in a newly installed rear axle may need to be adjusted. Technician A says that endplay is a measurement of how far the axle can be pulled out and pushed in after installation. Technician B says excessive endplay must be adjusted. Who is right?
    (A) A only.
    (B) B only.
    (C) Both A and B.
    (D) Neither A nor B.

Air bags are designed to inflate rapidly and absorb the forward, or lateral, energy of a vehicle's occupants during a collision. Air bags are part of a safety system that also includes seatbelts, high-strength steel door beams, and a padded dashboard. All of these systems work together to protect passengers from injury. (Ford)



Chapter 23

Restraint Systems

Objectives

After studying this chapter, you will be able to:

- List the different types of restraint systems and their components.
- Explain the differences and function of active and passive restraint systems.
- Describe the two types of air bag systems.
- Explain the function of the different impact sensors.
- Diagnose restraint system problems.
- Identify and know how to replace restraint system components.
- Understand the safety procedures and inherent dangers of servicing restraint systems.

Technical Terms

active seat belts
air bag module
air bag systems
clock spring
coil spring impact sensor
passive seat belts
safing sensor
wiring harness

Introduction

There are many types of collisions, including front-end collisions, rear-end collisions, rollovers, side-hits, and any combination of these. Collisions range from mild to severe. Factors contributing to the severity of a collision include the design and weight of the vehicle, the properties of the object the vehicle collides with, the speed of the vehicle, and the angle of impact. The most important consideration in a collision is protection of the vehicle's occupants. Restraint systems are designed to protect a vehicle's occupants during a collision. Restraint systems have gradually improved, beginning with seat belts installed as standard equipment during the 1960s. In earlier vehicles, the occupants could be thrown through the windshield or window, hit the metal dashboard with their head or knees, or be impaled on the steering column. In a rear collision, where a stopped vehicle is hit from behind, the vehicle occupants' heads would snap rearward. Studies of crashes showed that vehicle occupants sustained less injury if they remained in their seats. The object of a restraint system is to keep the vehicle's occupants securely seated during a collision and to prevent occupants from striking interior components such as a steering wheel or window.

Restraint System Types

Restraint systems can be classified into three groups: interior components, seat belts, and air bags. Interior components help restrain the vehicle's occupants. Most interior components, such as the seats and the dashboard, also serve other functions. Seat belts prevent the occupants from being thrown from their seats during a crash, and are considered the primary restraint system. Air bags deploy during a collision. The inflated air bags absorb the movement of the vehicle's occupants during a collision, protecting them from the forces of extreme deceleration.

Interior Components

Seats

Seats are an integral part of the restraint system because the occupants are confined in the seats by seat belts. There are two types of seats: bucket seats and bench seats. A bucket seat is designed to accommodate one person, while a bench seat can accommodate as many as three people.

Seats consist of a metal framework covered with foam and upholstery. The metal framework is securely bolted to the floor of the vehicle. The major parts of a seat are shown in **Figure 23-1**. The seat back is bolted to the seat bottom. The angle of the seat back can be adjusted on most bucket seats. The headrest acts as a restraint during a rear collision, preventing the occupant's head from being thrown rearward. Some vehicles have seat-mounted side impact air bags. Air bag systems will be discussed in a later section of this chapter. Additionally, seats may be electrically heated and, in some cases, cooled.

The front seat can be adjusted forward or rearward to position the occupant closer or further away from the instrument panel. Power seats have several electric motors to adjust the seat forward or rearward, raise or lower the seat bottom, or change the angle of the seat back. Rear seats, except in some vans and SUVs, are usually not adjustable.

The level of protection afforded by the seat is dependent on the integrity of the seat mount and the metal framework of the seat. The seat cannot protect its occupant if it moves during a crash.

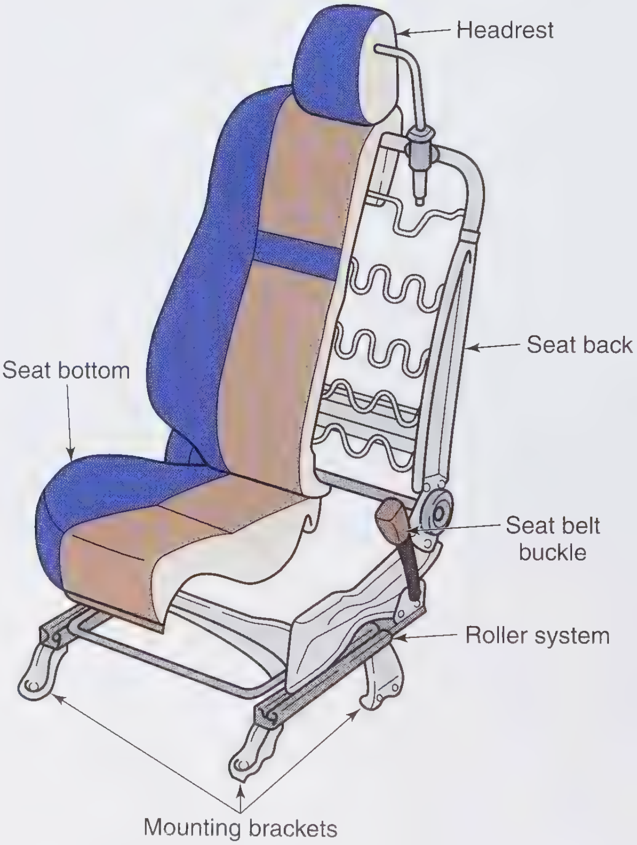


Figure 23-1. *The parts of the seat include the seat back, seat bottom, and rollers. The level of protection afforded by the seat is dependent on the integrity of the seat mount and the metal framework of the seat.*

Dashboard

The dashboard is made of rigid plastic and soft padded plastic. The assembly is bolted to an internal metal reinforcement bar that is bolted to the cowl. During a front-end collision, if unrestrained front seat occupants are thrown forward, they can be jammed under the dashboard. The knee bolster is designed to block the forward motion of the occupants. A knee bolster is shown in **Figure 23-2**. Some vehicles are equipped with an air bag at the knee bolster. This air bag deploys at the same time as the driver air bag. The right-hand portion of the dashboard contains the passenger air bag.

Steering Column

The steering column is designed to collapse and absorb, rather than resist, the forward motion of the driver during a collision. The driver, who moves forward as the vehicle stops in a crash, may hit the steering wheel. The impact energy travels through the steering wheel to the steering column. The collapsing steering column absorbs some of the collision energy that could injure the driver.

Windshield

The windshield serves as a backstop during passenger air bag deployment. The urethane bond of a properly installed windshield is strong enough to keep the windshield in place during air bag deployment.

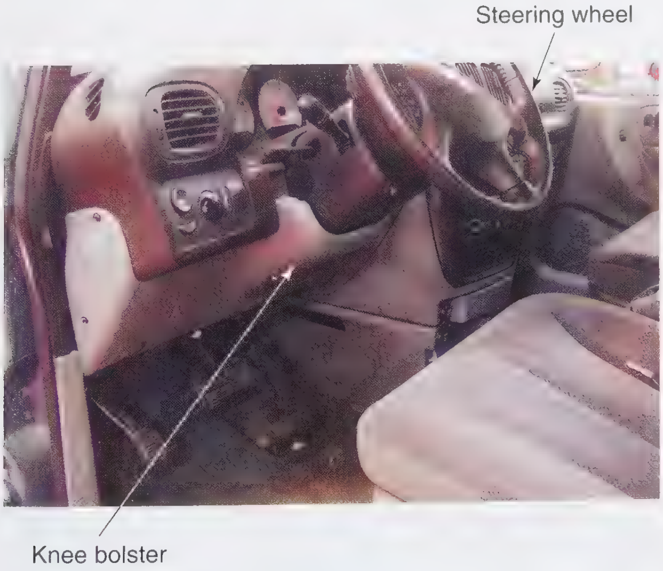


Figure 23-2. *The knee bolster acts as a blocker to prevent the driver from sliding under the dashboard during a collision.*

If the windshield is not properly installed and the bond between the windshield and pinch weld is weak, the windshield will be pushed out of place during air bag deployment. If the air bag pushes the windshield out, the air bag cannot properly protect the vehicle's occupants. When the passenger air bag deploys, the dashboard cover over the air bag flies open and may break the windshield. **Figure 23-3** shows a windshield that was broken by passenger air bag deployment.

Seat Belts

Seat belts keep the seat occupant in the seat during a collision. Seat belts that must be buckled by the seat occupant are called active seat belts. Seat belts that do not require buckling but automatically move into place each time the vehicle is driven are called passive seat belts. All new vehicles are equipped with a seat belt for each seat occupant.

Active Seat Belts

Active seat belts must be buckled by the vehicle's occupants. There are two types of active seat belts: lap belts and shoulder belts, or shoulder harnesses. During a frontal collision, an unrestrained occupant will be thrown forward. The lap belt, which is fastened around the hips, prevents a person from being thrown through the windshield. However, the upper body is still thrown forward and could hit the dashboard or steering wheel. The shoulder belt restrains the upper body. The head will still be thrown forward, but it will only hit the steering wheel or dashboard if the seat is positioned close to the steering wheel. In a rear end collision, the headrest and seat back keep an occupant's head and body from being thrown backward.

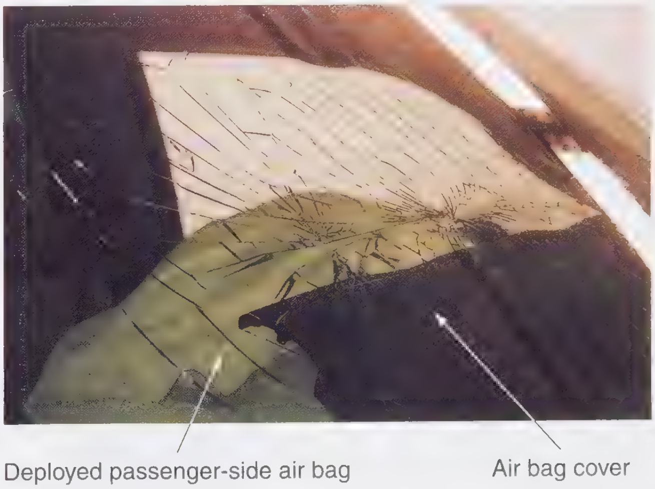


Figure 23-3. *Passenger air bag cover broke the windshield during deployment.*

The lap belt is also called a two-point seat belt because the seat belt is mounted to the vehicle at two places, to the floor of the vehicle at the end of each belt. A combination lap belt and shoulder harness is called a three-point seat belt. This type of belt is mounted to the vehicle at three places: to the floor at the end of each seat belt and to the center pillar or to the rear pillar at the shoulder belt.

Seat belts are the primary restraint system in a vehicle. The supplemental restraint systems (air bags) are intended to add to the protection the seat belt provides. During the rapid deceleration of a collision, the strain of lap and shoulder belts on the vehicle's occupants can cause bruising.

The parts of an active seat belt system are shown in **Figure 23-4**. The lap belt and shoulder belt are made of nylon webbing. On some vehicles, the middle passengers in the front and rear seats have lap belts only. The latch plate locks into the latch, or buckle, to fasten the belt around the seat's occupant.

The anchor eyes are attached to seat belt anchors with a high-strength bolt. A seat belt anchor is a reinforced area of the sheet metal body. A nut is welded to this reinforced area.

The seat belt retractor is a reel-like mechanism that allows the belt to be slowly pulled out to fit the occupant. Because the amount of belt and harness required is determined by the size of the seat occupant, the retractor adjusts the length of the belt and harness as needed. The retractor locks during a collision to prevent the occupant from moving. This device allows the occupant to move somewhat while driving, but will not permit movement if a crash occurs. Retractors are capable of sensing the sudden, rapid forward movement of the seat occupant during crash-induced deceleration and will lock accordingly. The retractor is also bolted to a seat anchor.

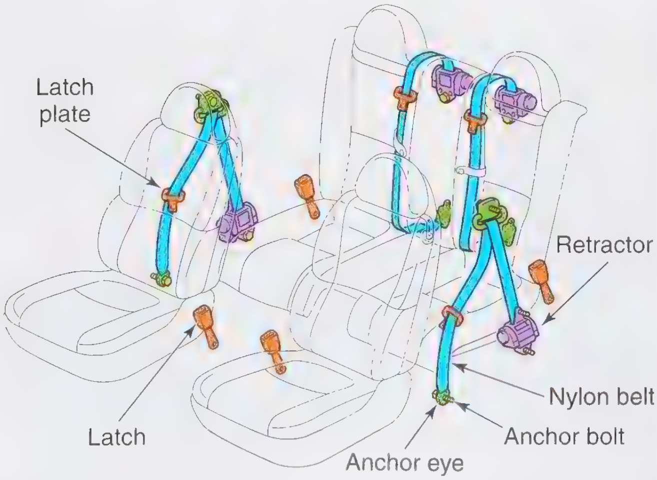


Figure 23-4. *The parts of an active seat belt system are shown here. This is the most common type of system found in late-model vehicles.*

NOTE

The bolts securing seat belt anchor eyes and retractors must be torqued to a specified value.

On most vehicles, the retractors and anchors for the front seat belts are located in the center pillar on four-door vehicles and in the rear pillar on two-door vehicles. **Figure 23-5** shows a different type of seat belt mounting. This seat belt system is only attached to the seat and is not directly attached to the body of the vehicle. Another seat belt anchoring system is shown in **Figure 23-6**.

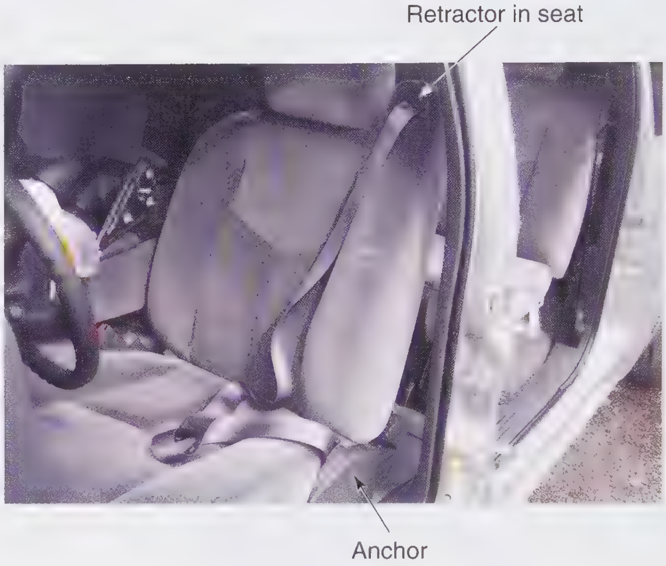


Figure 23-5. *This seat belt is attached to the seat only and not the floor.*

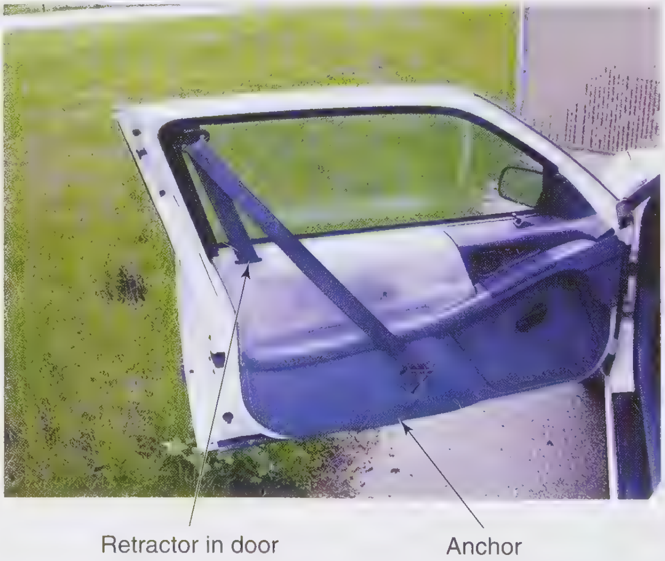


Figure 23-6. *The seat belt is in the door.*

The seat belt retractor and anchor are mounted inside the door. The door-mounted seat belt works in the same way as a pillar mounted system.

A warning lamp alerts the occupants when the vehicle is running and the seat belts are not fastened. Some systems are also equipped with a buzzer or chime to let the occupants know the seat belts are not fastened. Systems will continue to warn occupants until the seat belts are fastened.

Some vehicles are equipped with seat belt pretensioners, which tighten the seat belt or retractor during a collision. The tightening either properly positions the seat occupant for air bag deployment or holds the seat occupant in place during a collision. The pretensioner is controlled by a computer module that can respond appropriately, depending on the severity of the crash. The response hierarchy will be explained in the air bag section of this chapter. Tightening of the seat belt can be performed by an electric motor or by an explosive charge. The explosive charge is more common. The tightening can occur in the seat belt or the retractor. See **Figure 23-7**. On one type of system, when the computer module signals the pretensioner to tighten, an electrical signal to the igniter causes an explosion and gas production. The gas moves a piston, which in turn pulls a cable that tightens the seat belt. Once a pretensioner has fired, it cannot be used again.

The seat occupant can be injured by the seat belt during a severe crash. The shoulder belt can cause bruising as the occupant is forced against the seat belt during violent deceleration.

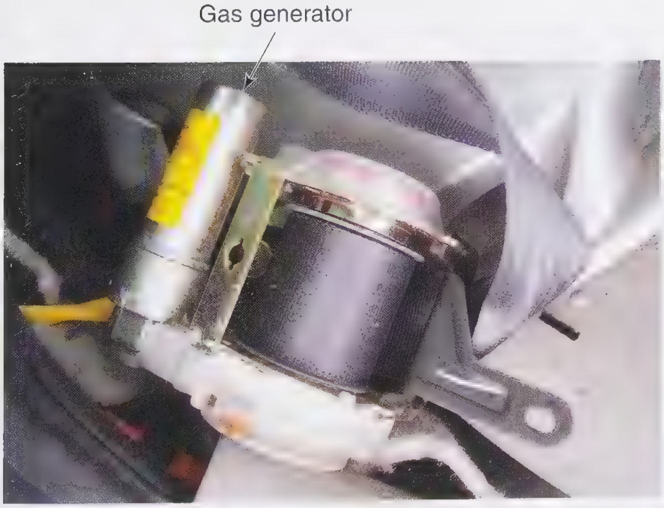


Figure 23-7. *This pretensioner tightens the retractor. Note the pyrotechnic gas generator. The exploding gas shoves the piston forward, pulling the cable and tightening the seat belt.*

Passive Seat Belts

A ***passive seat belt*** system requires the front seat occupants to fasten only the lap belt. With this system, the shoulder harness is at the forward position when the door is opened. When the door is closed, the harness automatically moves to the rear position, strapping in the seat's occupant. An example of a passive seat belt system is shown in **Figure 23-8**.

Air Bags

Air bag systems may be called by several names, including: inflatable restraints, supplemental inflatable restraints, and supplemental restraint systems. By any name, air bags are designed to inflate rapidly and absorb the forward, or lateral, energy of a vehicle's occupants during a collision. The air bags are designed to work in conjunction with the seat belt system, not to replace it. The occupants must be buckled in place for the air bags to adequately protect them.

WARNING

Air bags deploy with a deadly force. Safety must be a continual concern when working on an air bag system.

During basic air bag operation, a sensor detects an impact. The sensor sends an electrical impulse to a control module. The control module sends an electrical impulse to the air bag. The air bag inflates, absorbing the energy of the moving occupant, and then the air bag immediately deflates. All of these actions take place in less than one second.

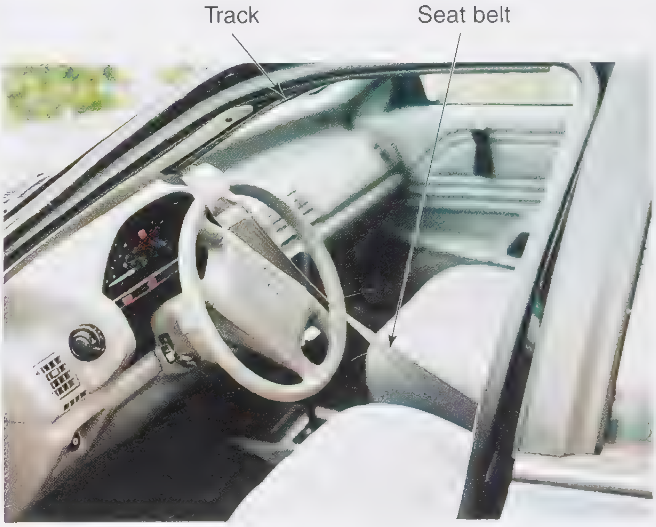


Figure 23-8. *A passive seat belt runs on a track.*

Front-Impact Air Bags

Air bags are designed to deploy during a collision of sufficient severity. The threshold for deployment requires that the vehicle be traveling at least 15 mph and strike head-on into a solid, immovable object. The vehicle must come to a dead stop immediately and the impact must be within 30 degrees left or right of the vehicle centerline. Most collisions do not happen this way. If a vehicle hits a parked car or another object that moves from the impact, the threshold speed may be 30 mph. However, if the vehicle does not stop immediately the air bag will not deploy. The impact, if not head on, must be within 30 degrees, left or right, of the vehicle centerline.

The visible damage on a vehicle is not always the best gauge of whether the air bag should or should not have deployed. For example, an impact that strikes the vehicle above the frame, causing considerable damage to the weaker structure above the frame but not causing the vehicle to stop immediately, may not deploy the air bags. An impact on the frame that stops the vehicle immediately, but does not produce as much readily visible damage, may deploy the air bags.

A parts diagram of a basic air bag system is shown in **Figure 23-9**. Components include: left and right impact sensors, a safing sensor, passenger and driver air bag modules, clock spring, control module, battery, and wiring.

The impact sensors and safing sensor detect the rapid deceleration caused by a collision. There are two types of impact sensors. One type uses a gold-plated ball that is held in place by a magnet. If the deceleration force is great enough, the ball will break free from the magnet and roll to the electrical contacts, completing a circuit. When the electrical contacts are closed, an electrical impulse is sent to the control module, which signals the air bag to deploy. Another type of impact sensor is shown in **Figure 23-10**. This is called a ***coil spring impact sensor***. Rapid deceleration causes the sensor's roller to be thrown forward. The roller touches the electrical contacts, sending an electrical signal to the control module.

Most impact sensors have an arrow on their case. The arrow should point toward the front of the vehicle when the sensor is installed. The impact sensor may be mounted on a bracket or fastened to the radiator support. If a vehicle has impact sensors, there are usually two at the front of the vehicle.

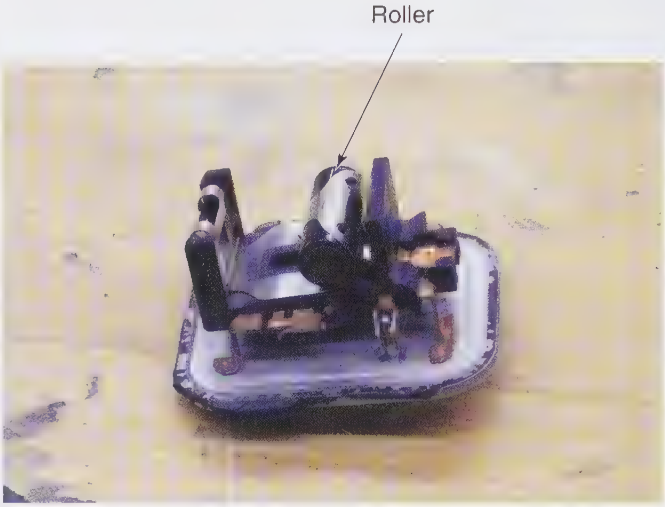


Figure 23-10. *The inertia created by sudden deceleration causes the roller to unwind forward and touch electrical contacts, activating the sensor.*

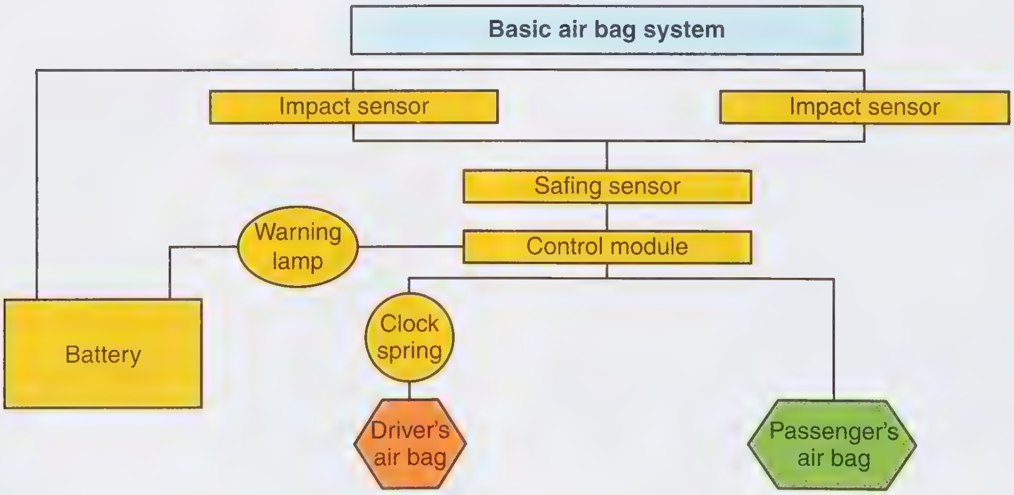


Figure 23-9. *In the basic air bag system, both air bag modules deploy if at least one impact sensor and the safing sensor close, completing the circuit.*

The ***safing sensor*** is also used to detect rapid deceleration. The safing sensor is usually located on the cowl or inside the control module. If one or both impact sensors send a signal to the control module, the air bag will not deploy unless the safing sensor also detects the rapid deceleration and signals the control module.

The control module contains a backup power supply that allows the air bag to deploy even if the battery cable is cut. The backup power supply does not last very long, only a few minutes. The control module also performs a self-diagnostic check of the air bag components every time the ignition is turned on. During the check, the air bag lamp on the instrument panel is illuminated. Once the self-check is completed and the components are determined to be functional, the lamp shuts off. If a problem is detected, the lamp remains illuminated after the self-diagnostic check is completed. The control module will also store a trouble code to help the technician identify the problem. The control module is usually located inside the instrument panel or the console.

The ***air bag module*** contains the folded air bag and the inflater substance. Front air bag modules are generally located on both the driver's side and the passenger side of the vehicle. The driver-side air bag module is bolted to the steering wheel. The passenger-side air bag module is generally located above the glovebox on the passenger side of the vehicle. See **Figure 23-11**.

In a driver-side air bag, the inflator substance may be made up of sodium azide pellets. See **Figure 23-12**. These pellets are ignited by an electrical impulse sent from the control module. As the sodium azide pellets burn, they produce a nitrogen gas that instantly inflates the air bag. Holes on the back of the air bag allow the gas to escape after the bag inflates. This entire process, which takes place in less than a second, is carefully timed. The occupant should contact the air bag just as the air bag reaches full inflation. The air bag deflates immediately after contact with the occupant.

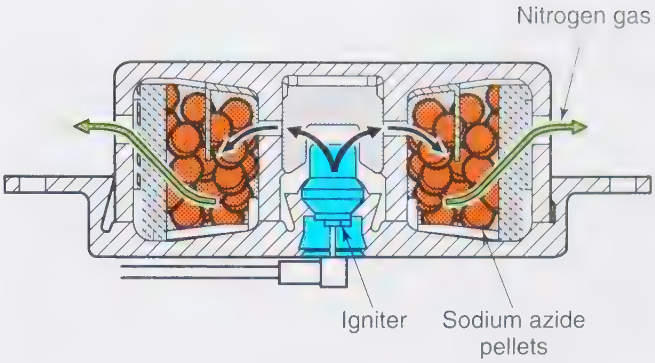


Figure 23-12. *The electrical current moving through the igniter creates heat and causes the sodium azide pellets to burn. The burning pellets produce nitrogen gas that rapidly inflates the air bag. (Toyota)*

The passenger-side air bag is three times larger than the driver-side air bag. It may use sodium azide to inflate the air bag. Another way to deploy a passenger-side air bag is by explosive charge. The blast breaks the seal on a container of pressurized argon gas, which inflates the air bag. The passenger-side air bag deploys in the same way as the driver-side air bag, but it inflates against the windshield to prevent the passenger from hitting the glass.

Both the driver-side and passenger-side air bags are lubricated with sodium hydroxide powder. This allows the folded bag to inflate without binding. The sodium hydroxide will leave a dust layer inside the vehicle after air bag deployment.

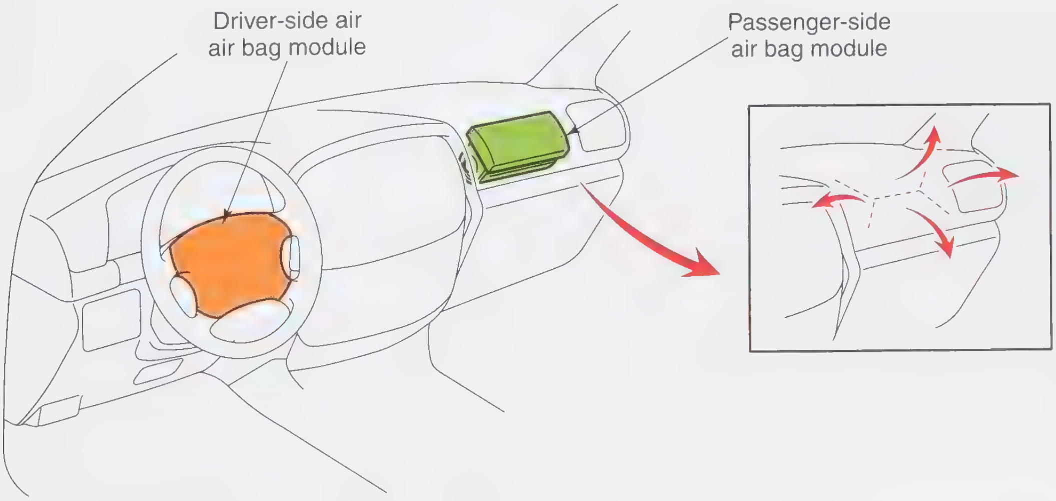


Figure 23-11. *The front air bag modules are located on both the driver's side and the passenger side of the vehicle. (Toyota)*

A ***clock spring*** is used to maintain the electrical connection between the driver-side air bag module and the wiring harness, **Figure 23-13**. The clock spring is located in the steering column, under the steering wheel. The clock spring contains a spool of wire that winds and unwinds as the steering wheel is turned. The ***wiring harness*** provides the electrical pathway through the air bag system. The harness connects the impact sensors, control module, and clock spring. There are two types of clock springs. One type of clock spring is a separate unit; the other type is part of the turn signal-windshield wiper control unit

In some air bag systems, the air bag control module, mounted under the front passenger's seat or under the console, detects the deceleration of a crash. The control module contains a micro electromechanical system (MEMS) called an accelerometer. These systems have evolved to a point where they can reliably and accurately detect and measure deceleration, tilt, and the shock of impact, in automobile safety applications. The accelerometer does the job of the impact and safing sensors by detecting the deceleration that occurs during a collision. **Figure 23-14** shows the inside of an air bag control module.

Single-stage air bags deploy at one level of intensity. The intent is to protect someone who is held in place by the seat belt and is at least 10" away from the steering wheel (driver air bag) or 18" away from the dashboard (passenger air bag). Deployment could disable or even kill an individual who is too close to the air bag or is otherwise out of position during deployment. A shortcoming of early air bag systems was people, especially children, were being killed by the passenger air bag. Injuring or killing the occupants is the exact opposite of the intended purpose of an air bag system. To remedy this undesirable consequence, the driver was given the option of turning off the passenger air bag if a child was in the passenger seat. Some single-stage bag systems have a switch that allows the vehicle driver to use the ignition key to turn off the passenger air bag. Vehicle manufacturers recommend that all children ride in the rear seats of a vehicle.

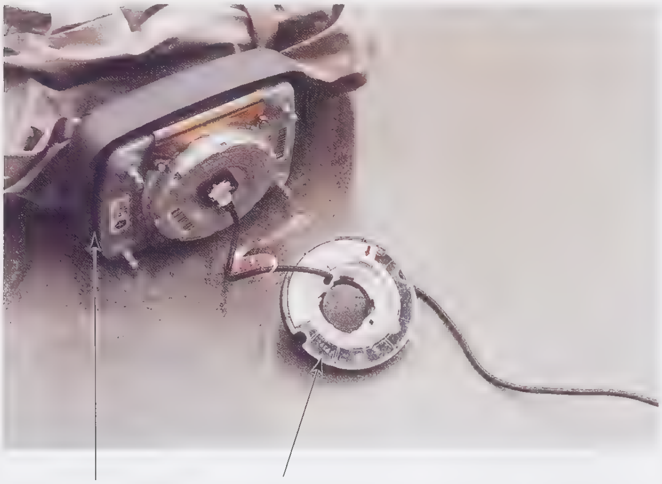


Figure 23-13. *This clock spring is shown attached to the air bag module.*

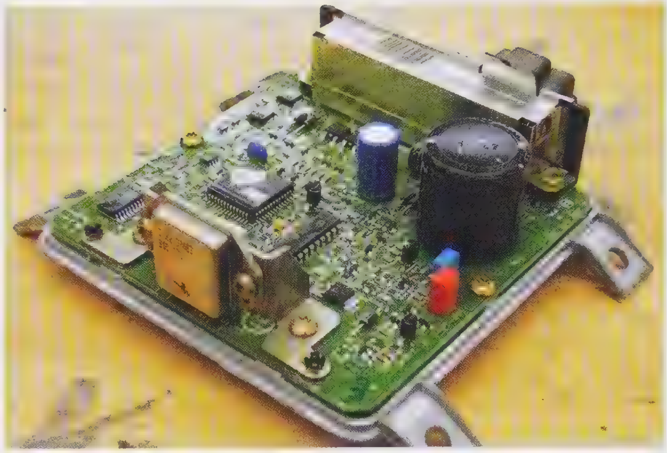


Figure 23-14. *The air bag control module is mounted on the floor under the front passenger seat or under the console.*

Advanced Air Bag System

Advanced air bag systems, or dual-stage air bag systems, were designed to correct some of the dangers of the single-stage air bag systems and to add additional protection for side impacts and rollover crashes. The advanced system is capable of determining the severity of the crash and responding appropriately. For example, in a mild collision the seat belts alone may offer enough protection. The restraint system detects this and does not deploy the air bags. In a slightly more severe impact, the seat belts may need to be tightened by firing the pretensioners. In a moderately severe crash, the pretensioners may fire and the front air bags deploy. The pretensioners tighten the seat belt so the occupants are in the correct position for maximum effectiveness during air bag deployment.

The force with which advanced air bags deploy depends on the severity of the crash. The air bag is equipped with two charges, **Figure 23-15**. In a severe collision, the charges fire at the same time and the bag deploys at maximum speed and force. In a less severe crash, one of the two charges fires, then, a fraction of a second later, the other charge fires. In most systems, the second charge does not fire in moderate impacts. It is not "sequential." You either get one or both. This two-stage deployment uses less force and is safer for the occupants. In some air bag systems only one charge may fire and the other charge may not. This creates a safety concern for the technician as the deployed air bag is capable of re-inflation. Most collisions require less than maximum force to initiate air bag deployment.

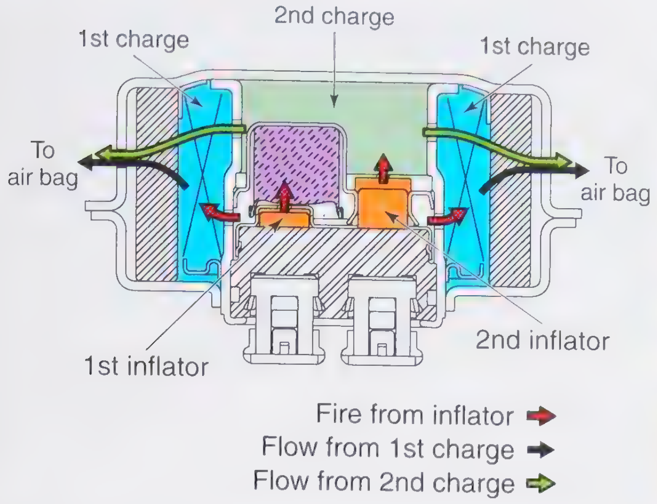


Figure 23-15. *A dual-stage air bag contains two charges. Notice that a dual-stage air bag also has two electrical connectors, one for each charge.*

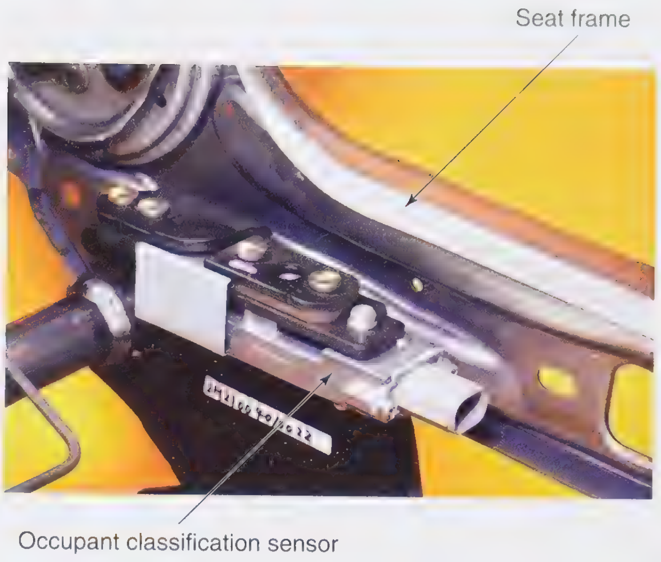


Figure 23-17. *This sensor is attached to the seat frame. It determines the weight of the seat occupant.*

An air bag can deploy in one of several ways, see **Figure 23-16**. A moderate/severe collision will prompt the system to fire one charge then the other charge. If the system detects a collision severe enough to require maximum air bag deployment, it will fire simultaneous charges. If the seat belts or one seat belt is not buckled at the time of the collision, the pretensioner for that seat will not fire. The pretensioner will not fire on an unbuckled seat belt.

One variable that an advanced air bag system can accommodate is a child, child car seat, small adult, or an out-of-position person sitting in the front passenger seat. The passenger seat has a sensor, or sensors, to determine the weight and position of the seat occupant. See **Figure 23-17**. These seat sensors can detect occupants who may be prone to injury by air bag deployment. That information is sent to the control module, which will turn off the passenger air bag to protect vulnerable individuals. The driver is alerted to the situation by the glow of the "air bag off" light in the instrument panel or in the rear view mirror. **Figure 23-18** shows how the passenger seat occupant determines air bag operation.

Front Passenger Air bag	**Passenger's Seat Occupant**		
	Adult	Child	Child Seat
Front Air bag	O	—	—
Side Air bag	O	—	—
Curtain Shield Air bag	O	O	O
Seat Belt Pretensioner	O	O	O

O ON, — OFF

Figure 23-18. *If the seat sensor detects a child or a child seat, the passenger air bag and the side air bag are turned off.*

Collision	**Seat belts**	**Seat belt pretensioners**	**Staggered charge ignition**	**Simultaneous charge ignition**
Mild	x			
Moderate	x	x*		
Moderate to Severe	x	x*	x	
Severe	x	x*		x

* seat belts must be buckled

Figure 23-16. *Depending on the severity of the crash, an advanced air bag system features multiple deployment options*

Another variable that an advanced air bag system can take into account is the distance of the seat occupant from the undeployed air bag. A short person or child may move the seat too close to the dash. This may put the person in the danger zone for air bag deployment. Advanced air bags address this problem. A sensor sends info on the position of the seat to the air bag control unit. If the seat is too close to the dash when the air bag deploys, a tether on the bag limits the inflated air bag to half the full inflated size. If the seat is back, and no one is in the danger zone, the tether is not needed and the air bag deploys at full size.

The advanced air bag system control module records collision information in much the same way as a black box in an airplane records crash data. The control module can record the following information and more: vehicle speed at the time of the accident, seat belt usage, engine speed, steering wheel angle, throttle position, transmission range, low tire pressure warning system status, and vehicle doors open or closed.

All new vehicles feature driver and passenger air bags. Most vehicles are also equipped with side impact air bags and many are equipped with side curtain air bags. See **Figure 23-19**. The side impact air bags deploy from the seat, door, or pillar to protect the occupant's head or neck during a side impact. The action of the side impact air bag is similar to a front air bag. A sensor detects the impact and sends the information to a control unit. The control unit decides what action to take and may send a signal to the side impact air bag to deploy.

The sensors for the side impact air bags may be in the door, center pillar, roof rail, or quarter panel. There are two scenarios where the sensor will initiate air bag deployment: if the vehicle is sliding sideways, and hits an object, or if the vehicle is hit in the side.

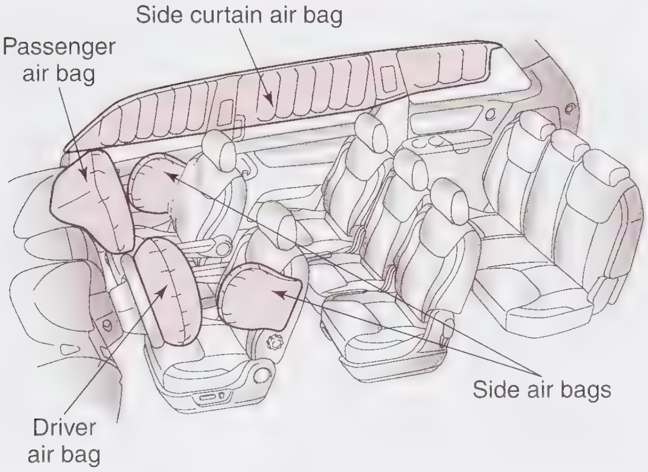


Figure 23-19. *This diagram shows an advanced air bag system with driver and passenger air bags, side air bags, and side curtain air bags. All of these air bags will not necessarily deploy at the same time. (Toyota)*

The side curtain air bags operate in a slightly different way. The side curtain air bag sensor detects that a rollover is occurring and sends a signal to the control unit. The control unit decides whether to deploy the side curtain air bag. The side curtain air bag is intended to not only cushion the occupants' heads but also to keep occupants inside the vehicle during a rollover.

There are at least four and as many as six sensors for side curtain air bags. These sensors are gyrometers. The gyrometers monitor the roll angle and roll rate of the vehicle. Information about roll angle of the vehicle body is important in predicting and sensing rollovers. This information is used in the MEMS algorithm controlling deployment of air bags in rollover events. If the vehicle runs off the road and begins to tip over, the gyrometer detects the roll angle and the rate at which the roll angle is changing. When a rollover is imminent due to an extreme roll angle, the gyrometer sends a signal to the control unit to deploy the side curtain air bags. Another way a vehicle can rollover is from a side impact. In this type of collision, the side impact air bag sensors and the side curtain air bag sensors may send signals to the control unit to deploy both the side impact air bags and the side curtain air bags.

WORKING GREEN

Both undeployed air bags and seat belt pretensioners contain potentially hazardous substances, such as sodium azide. The EPA left it up to each state to decide whether air bags and pretensioners are considered hazardous waste, and many states—including Oregon, Colorado, and Wisconsin—were quick to say yes.

KPA, a Colorado-based dealer services provider that serves 4,000 dealerships and service companies nationwide, is offering a recycling program to help its clients handle air bags and pretensioners properly and recover materials for recycling. Air bags and pretensioners recovered through the program are disassembled and more than 95% of the materials are recycled.

Restraint System Service

It is extremely important that all aspects of the restraint system be considered when repairing collision damage. Vehicles are designed to absorb the energy of an impact in a particular way. A repaired vehicle must absorb the impact in the same way.

In fact, the proper timing of air bag deployment is dependent on the vehicle absorbing the energy of an impact as designed. For the air bags to properly function, body repairs must return the vehicle to pre-accident condition. This means that the damaged vehicle's dimensions must be returned to pre-accident specifications. All kinked structural parts must be replaced, welds must be strong and correctly placed, and replaced panels must be treated to prevent rust.

The first step in restraint system repair is to consult the vehicle manufacturer's recommendations. The I-CAR website lists recommendations for restraint system repair. Other sources of information are aftermarket repair manuals. Always follow the recommendations fully.

Figure 23-20 is a list of restraint system components that must be replaced (on one type of vehicle) whenever the air bags deploy. **Figure 23-21** is a list of restraint system components that must be checked and replaced if damaged (on one type of vehicle) whenever the air bags deploy. Some manufacturers recommend that all sensors be replaced after a collision. Advanced systems require that the control module be replaced after air bag deployment. Often the recommendations are unique to each model of vehicle. Always consult the manufacturer's recommendations before beginning repairs.

Parts That Must Be Replaced Following Deployment

When a driver air bag deploys, replace:
- Clock spring
- Steering wheel
- Complete steering column assembly with lower steering column coupler
- Front seat belt buckle (driver and passenger) with integral tensioners
- Any damaged restraint system part
- Driver air bag

When a passenger side air bag deploys, replace:
- Passenger air bag
- Instrument panel and pad assembly
- Front seat belt buckle (driver and passenger) with integral tensioners
- Any damaged restraint system part

When a knee blocker air bag deploys, replace:
- Knee blocker air bag
- Instrument panel and pad assembly
- Any damaged restraint system part

When a side curtain air bag deploys, replace:
- Curtain air bag assembly
- Headliner
- A-, B-, C-, and D-pillar trim on deployed side
- Any damaged restraint system part

Figure 23-20. *This manufacturer requires the replacement of the driver air bag, clock spring, steering wheel, steering column assembly, and seat belt system if the vehicle has pretensioners, and replacement of any damaged system component if the driver air bag deploys.*

Parts That Must Be Inspected and Replaced If Damaged

When a front air bag deploys, replace:
- Steering column
- Instrument panel knee bolsters and mounting points
- Instrument panel brackets, braces, etc.
- Instrument panel mounting points and brackets
- Roof rail and roof rail module
- Seats and seat mounting points
- Steering wheel module coil wiring pigtail
- Seat belts not in use during the collision
- Mounting points or mounting hardware for the instrument panel module, steering wheel module, SDM, front-end sensors, seat belt pretensioners, and vehicle rollover sensors
- Passenger presence system
- Any restraint system part or wiring identified by diagnostic check

When a side air bag deploys, replace:
- Steering column
- Instrument panel knee bolsters and mounting points
- Instrument panel brackets, braces, etc.
- Instrument panel mounting points and brackets
- Roof rail and roof rail module
- Seats and seat mounting points
- Seat cushion frame
- Seat recliner, if equipped
- Seat adjuster
- Seat back frame
- Mounting points or mounting hardware for the SIS, roof rail module (left/right) and seat belt pretensioner on the impact side
- Mounting points or mounting hardware for the SDM and the vehicle rollover sensor.
- Any restraint system part or wiring identified by diagnostic check.

Figure 23-21. *A list of parts that must be inspected and replaced if damaged.*

Checking Components

Check for damage to restraint system components at the point of impact. In some systems, the impact sensors are mounted on the radiator support. Look for a cracked case, bent mounting tabs, or cut wires on sensors. Some manufacturers may allow a cut wire to be spliced using a special splicing kit.

Next, look inside the passenger compartment for the deployed air bag or bags. **Figure 23-22** shows a deployed driver-side air bag. If the vehicle has advanced air bags, disable the restraint system as described in the "*Disabling the System*" section that follows. If the collision was moderate in intensity, all the air bags may not have been deployed. This is why the system must be disabled. On a single-stage restraint system, this is not the case as all air bags have been deployed. Be sure to inspect all components listed by the manufacturer.

Check the steering wheel for bends. Remove the plastic trim around the steering column and check the column assembly for compression or heating. Compression is a shortening of the steering column caused by the driver slamming into it during the crash. Heat produced by air bag deployment may melt or deform the plastic components of the steering column. Look for heat discolored or warped plastic.

Check the instrument panel for misalignment or cracks under the steering wheel and around the passenger air bag. Cracks under the steering wheel mean damage to the knee bolster. Check the control module mounting area even if the air bags did not deploy. The mounting area must be returned to the proper shape before installing a new control module,

The clock spring can be inspected after the driver air bag module and steering wheel are removed. Many vehicle manufacturers require that the clock spring be replaced whenever the air bag system is repaired. A clock spring must be replaced if the case is cracked, scorched or melted; the wires are cut; or the manufacturer requires replacement. Check for deployed side impact air bags or side curtain air bags as shown in **Figure 23-23**.

Seat belts should always be inspected after a collision. Check the operation of the retractor. The reel should move smoothly without binding. Drive the vehicle at about 10 mph and then slam on the brakes. The retractor should lock up and not permit any forward movement. If damaged or worn, the retractor may not reel the belt in and out. If this problem occurs, the entire belt/harness should be replaced, including the retractor. Individual parts of the retractor should not be replaced.

The belts should be checked for stretched or torn webbing, torn threads, or cuts. **Figure 23-24** shows what worn seat belt webbing looks like. This seat belt must be replaced! During a crash, as the seat occupant strains against the seat belt, the seat belt may stretch. A stretched seat belt must be replaced. **Figure 23-25** shows the labels on seat belts that indicate when replacement is needed. Some manufacturers weave a special thread into the belt that is not visible unless the seat belt is stretched in a crash. Some manufacturers recommend the replacement of all seat belts in use during any collision that deploys air bags, regardless of stretching. If the seat belt must be replaced, replace the entire belt, not individual components.

The belt latch or buckle may also wear out. As with the retractor, the entire assembly, latch, and anchoring eye, should be replaced. If the reinforced area around the seat belt anchors is weakened by rust, the vehicle is no longer safe to drive. A triggered pretensioner must be replaced. Check the manufacturer's recommendations.

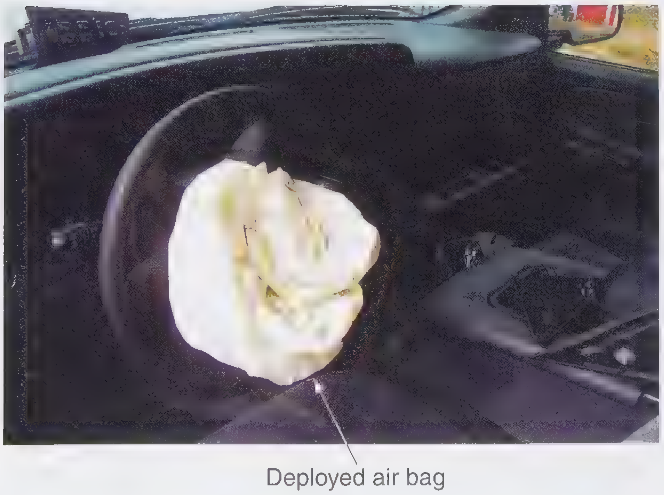


Figure 23-22. *The driver air bag has deployed. Notice that the passenger air bag did not deploy.*

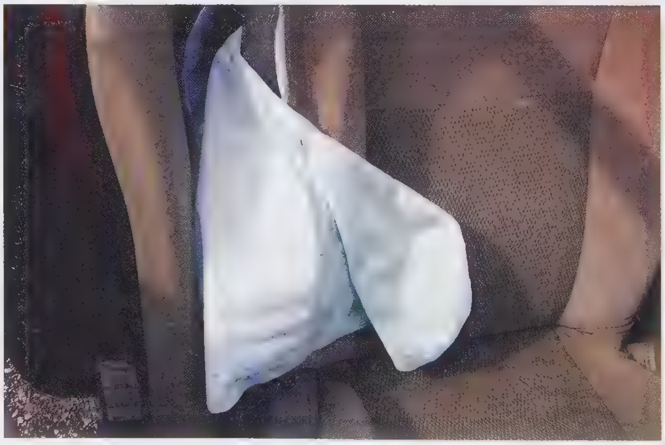


Figure 23-23. *The seat back ripped when this side air bag deployed.*

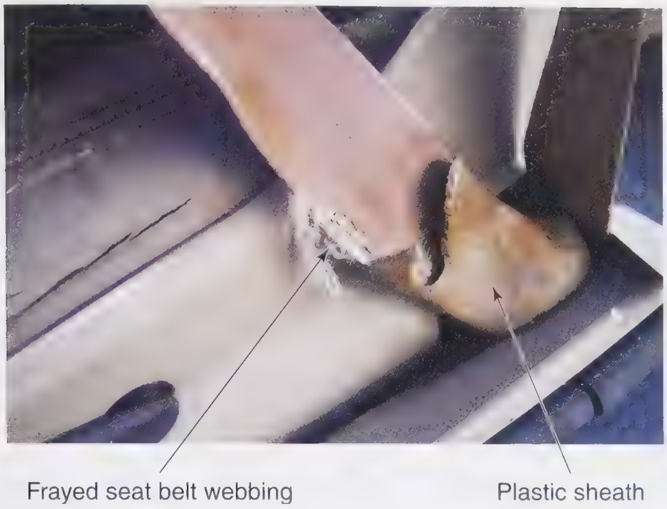


Figure 23-24. *Damage to the plastic sheath, probably caused by repeatedly shutting it in the vehicle door, caused the visible wear on the seat belt webbing. This seat belt is not safe and should be replaced.*

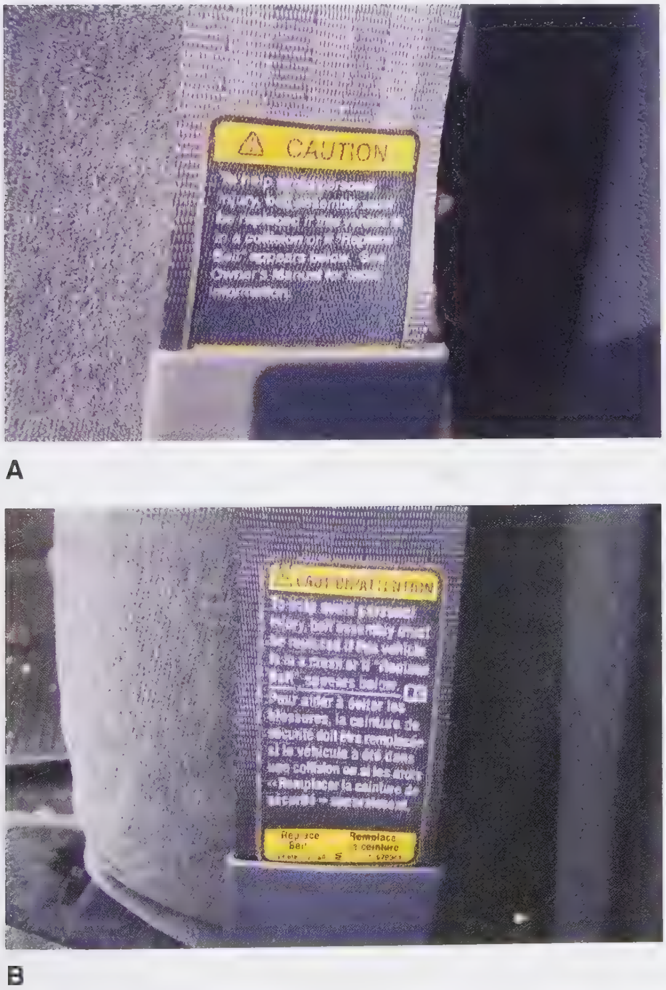


Figure 23-25. *A—This seat belt has not been stretched in a collision. B—This seat belt has been stretched in a collision. Note the yellow "replace belt" label at the bottom.*

Restraint System Service

Driver's air bag, passenger air bag, and side air bag systems are designed to be durable with no maintenance required. Whenever the vehicle is started, the air bag system goes through a self-diagnostic. The air bag light is lit during this check. Problems such as short circuits or improper sensor mounting will be detected by the self-diagnostic system. The air bag warning light will alert the driver or technician to problems. If all components check out, the warning light turns off and the air bag system will function properly if needed.

Safety

Air bags can deploy with deadly force. Safety must be a continual concern when working on an air bag system. Observe these rules:

- Follow the directions in the service manual for the specific vehicle being serviced.
- Carry an undeployed (live) air bag module pointing away from your body. See **Figure 23-26**.
- Set an undeployed air bag module face up. In the unlikely event that a module accidently deploys, the module deploys away from you.
- Disable the air bag system before servicing the steering wheel, dashboard, or any other areas where the system parts are located.
- Store air bag modules upright, as shown in **Figure 23-27**.
- Do not install used air bag system parts.
- Do not heat air bag modules to temperatures above 150°F (65.5°C) because air bags are designed to deploy at high temperatures.
- Do not touch the control module terminals. Electrostatic discharge may damage the control module.
- Never get a control module wet.

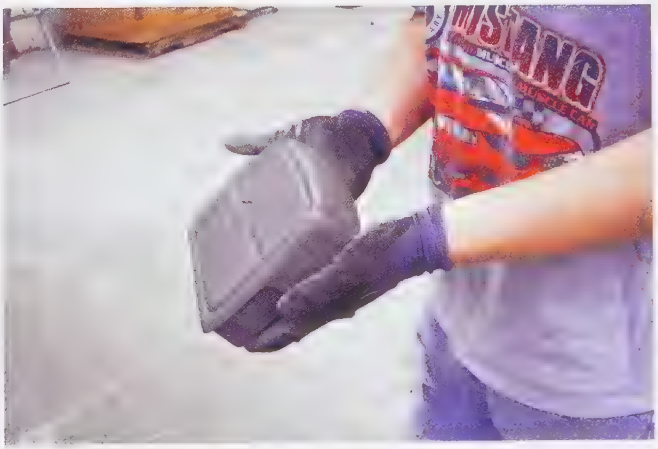


Figure 23-26. *Point an air bag module away from yourself when you carry it.*

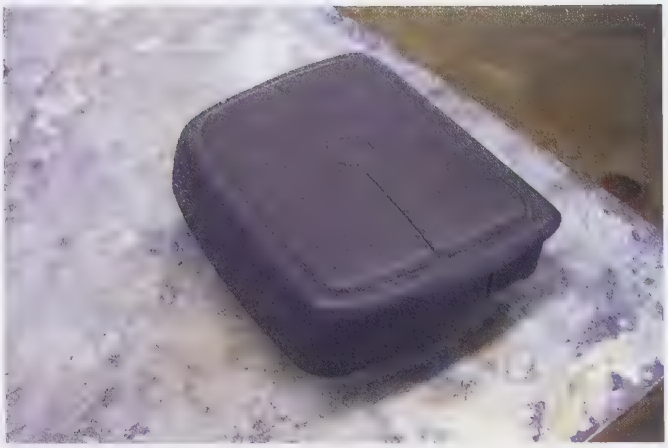


Figure 23-27. *Store an air bag module upright. Note that the cover faces away from the work surface.*

Clean Up

The deployment of an air bag will release sodium hydroxide powder inside the passenger compartment. Sodium hydroxide is a minor skin irritant; therefore, technicians should wear rubber gloves, safety glasses, and a dust respirator when cleaning up the powder. First, vacuum the vehicle's interior, including the air vents. Then, wipe the dashboard, steering column, pillars, and door panels with a damp rag or a tack cloth. Apply masking tape to the vent holes in the deployed air bag. This will keep any remaining powder inside the air bag.

Disabling the System

Air bag inflation requires an electrical impulse. The battery or back-up power supply provides the impulse when a complete circuit is made between the power supply, sensors, control module, and air bag. To prevent accidental deployment, the system must be disabled. The system should be disabled whenever it is serviced, even if the air bags have been deployed.

One manufacturer's recommended method of disabling involves disconnecting the negative battery cable. The cable should be tied out of the way so it cannot spring back and touch the battery. With the negative battery cable disconnected, the only source of electricity in the system is the back-up power supply. The back-up power supply may last up to thirty minutes. After waiting thirty minutes, the power should be dissipated and the air bag system inoperable.

WARNING

Air bags can deploy with deadly force! Carry an undeployed (live) air bag module pointing away from your body. Set an undeployed air bag module face up.

After disconnecting the battery, some manufacturers may recommend removing the air bag system fuse located in the side of the instrument panel. There are other ways to disable the air bag system during servicing. Make sure to follow the manufacturer's recommendation.

Diagnosing an Air Bag System

If the self-diagnostic system detects a problem, the air bag light on the dash will remain illuminated or it will blink. The light indicates that there is a Diagnostic Trouble Code (DTC) stored in the air bag control module's memory. After air bag deployment and before replacing any air bag system components, the technician should see which DTCs are present. Retrieving the DTCs will tell the technician exactly where the fault is.

DTCs are retrieved with a scan tool. This device is plugged into the data link connector in the air bag system and the ignition is turned on. The scan tool reads DTCs in the air bag system. To use the scan tool, the tool must have the correct cartridge for air bag diagnostics. A scan tool may also be required to clear the trouble codes.

NOTE

A scan tool can determine if both charges in a two-stage air bag have fired.

Replacing System Parts

Damaged restraint system parts must be replaced rather than repaired. The following are different types of replacement procedures for:

- Impact sensors.
- Air bag module.
- Clock spring.

To remove an impact sensor, remove the bolts that secure the sensor to the vehicle and disconnect the wire leading to the sensor. Clean the mounting area and position the impact sensor with the arrow pointing toward the front of the vehicle. See **Figure 23-28**. Install the mounting bolts in place and torque them to the manufacturer's recommended specifications. Finally, connect the sensor wires.

The driver-side air bag module fits into the steering wheel from in front and is fastened from behind. Fasteners can only be accessed from the back of the steering wheel. After removing the fasteners, pull out the module and disconnect the wiring. To replace the module, simply plug in the electrical connector and bolt in the module. See **Figure 23-29**. Be sure to torque bolts to specifications.

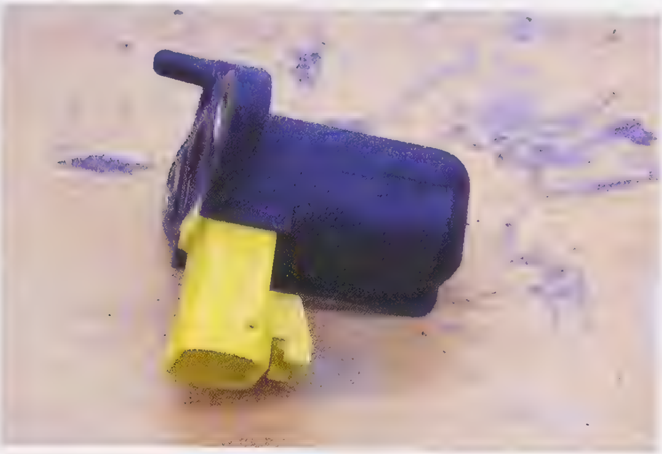


Figure 23-28. *This impact sensor should be installed with the arrow pointing toward the front of the vehicle.*

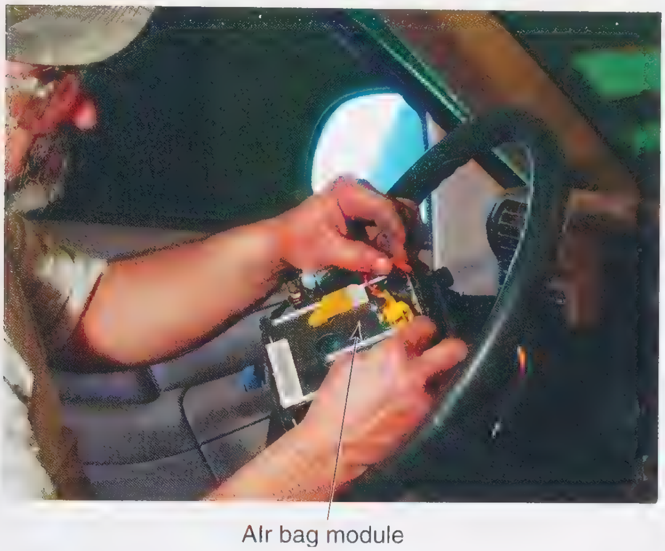


Figure 23-29. *Begin driver air bag module installation by plugging in the electrical connectors.*

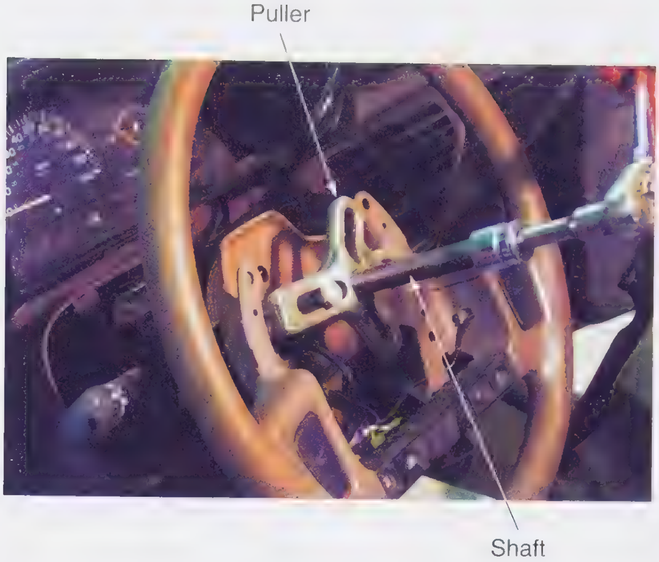


Figure 23-30. *A steering wheel puller is bolted to threaded holes in the steering wheel. The puller shaft pushes against the steering wheel mounting stud.*

To replace the clock spring, position the steering wheel in the straight-ahead position. Next, remove the driver-side air bag module. Some vehicles require that the steering wheel be removed. Remove the steering wheel with a steering wheel puller. See **Figure 23-30**. The puller anchoring bolts are inserted into threaded holes located at the base of the steering wheel, and the puller shaft pushes against the mounting stud in the steering column. Remove the steering column trim as needed to access the clock spring wiring connectors. Disconnect the clock spring from the wiring harness and pull the clock spring from the steering column.

Begin clock spring installation by sliding it into position. If the new clock spring has a locking tab for shipping, remove the tab at this time. If the clock spring is reused, it may require centering. Installing an uncentered clock spring will cause damage to the wires inside the clock spring as the steering wheel is turned. To center a clock spring, refer to the manufacturer's instructions. After the clock spring is centered, it can be connected to the wiring harness.

WARNING

Disable the air bag system before servicing the steering wheel, dashboard, or any other areas where the system parts are located.

The seat belt/harness is held in place by two bolts, one on the floor at the retractor and the other on the pillar. These bolts may have a Torx® head. The bolts are usually hidden under plastic covers. Remove the covers. Then, remove the belt/harness assembly. Install the new assembly and torque the bolts to the specified value.

The replacement of a fired pretensioner is similar to replacing a seat belt. First, read the manufacturer's recommendations on what must be replaced. The pretensioner is bolted to the floor in the same way as a seat belt. Unbolt the pretensioner assembly and unhook the electrical connector. Hook up the new pretensioner connector and bolt the pretensioner assembly into place. Tighten the fastener to the specified torque value.

A deployed passenger-side air bag may rip or tear the dashboard around the module lid opening. Replacement of a passenger-side air bag may require dashboard replacement. If the dashboard has not been torn, the deployed air bag module can be replaced with a new one. To remove the module from the dashboard, locate the mounting bolts. The glove compartment may have to be removed to access the bolts. If the entire dashboard does not need replacement, the air bag module can be unbolted and disconnected from the wiring harness. To replace the module, position the new module in the dashboard opening after connecting it to the wiring harness. See **Figure 23-31**. Bolt the module in place and torque bolts to recommended specifications.

NOTE

Some vehicle manufacturers allow splicing of the air bag system's wiring. Follow the manufacturer's wire splicing recommendations.

To replace a side impact air bag, the seat will need to be removed. Unbolt the seat from the floor. Tilt it backward, toward the rear seat, to expose the underside of the seat. Unplug any electrical connectors under the seat and remove the seat from the vehicle. Seats are heavy; get help. Some vehicles require that the entire seat back be replaced when replacing a side air bag. Other manufacturers require seat removal when the side impact air bag is replaced, but only the side module is replaced in the seat back. The entire seat back is only replaced if it is damaged. If only the module needs to be replaced, remove the trim, if any, surrounding the module. Unbolt the module from the seat and disconnect it from the wiring harness. Install the new module by connecting it to the wiring harness and bolting the module in place. Install the module bolts and torque them to the specified value. Install the seat in the vehicle after plugging in the electrical connectors. Torque the seat bolts to the specified value. If the entire seat back must be replaced, unbolt the seat back from the seat bottom. Disconnect the wiring harness. Install the new seat back after plugging in the electrical connectors. Bolt the seat in place and torque all fasteners to the specified value.

To replace side curtain air bags, the obstructing trim and headliner must be removed, or at least loosened, to expose the electrical connector and the fasteners, guides, and clips that hold the side curtain air bag in place. **Figure 23-32** shows what an exposed side curtain air bag looks like. Follow the manufacturer's recommendations when removing the fasteners and installing the new side curtain air bag. Replace the headliner and trim.

Replacement of the instrument panel will require the disconnection of at least 50 electrical connectors. Unless the reconnection is unmistakable, mark each electrical connector as they are separated. This will make reconnection much easier. For example, when separating an electrical connection, put a piece of masking tape marked with #1 on both connectors. Mark the next separated connectors as #2, and so on.

The instrument panel is bolted to the cowl at the corners. See **Figure 23-33**. Some electrical connectors may only be accessible after the instrument panel is unbolted and moved slightly. To reinstall, first put together the connectors that are only accessible with the instrument panel out of position. Then bolt the instrument panel in place. Reconnect the remaining electrical connectors. Torque the instrument panel bolts to the specified torque value.

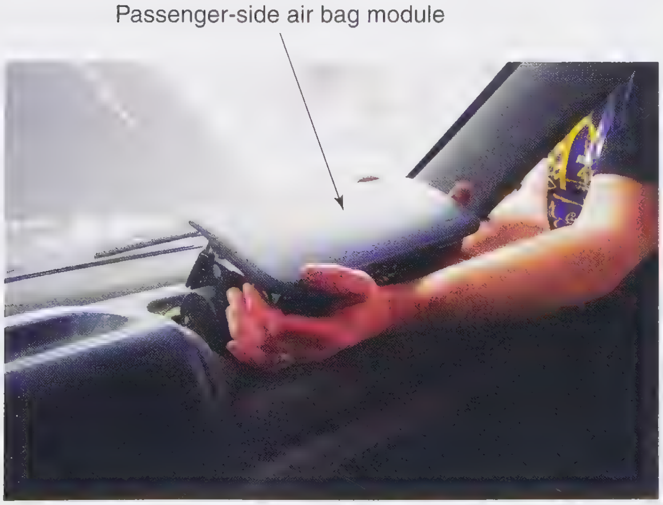


Figure 23-31. *The passenger-side air bag module slides into the dashboard opening. Notice that the technician is not positioned directly in front of the air bag module.*

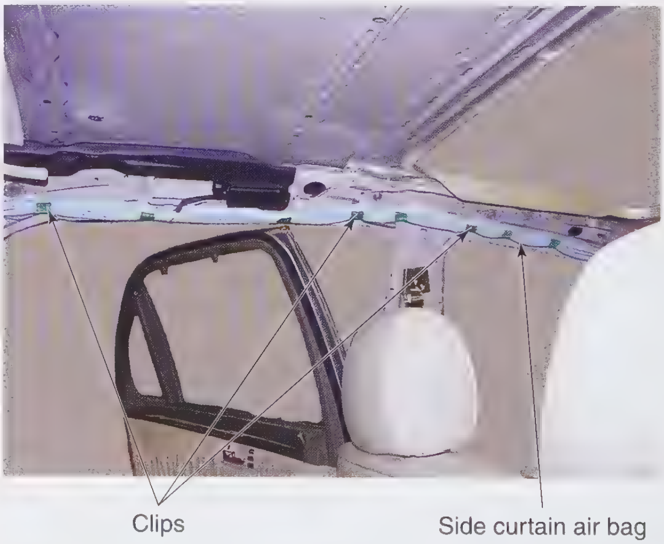


Figure 23-32. *The side curtain air bag is held in place with clips.*

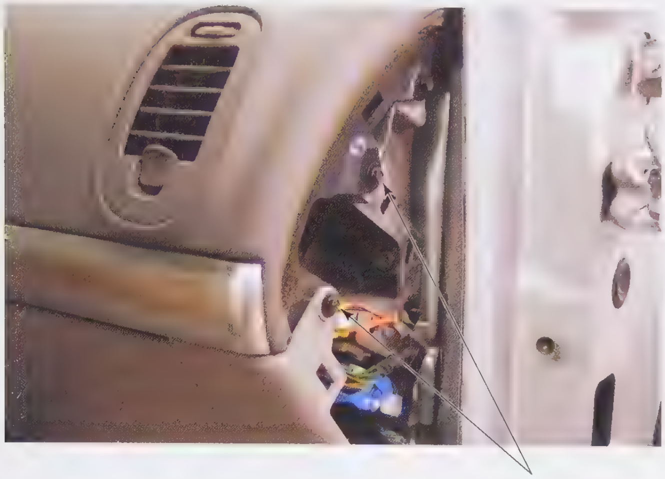


Figure 23-33. *The three small bolts hold the dash pad to the reinforcement. The large bolt holds the reinforcement to the cowl.*

Some vehicle manufacturers may require that any existing trouble codes be cleared and the seat occupant sensor be reset with a scan tool before the vehicle is released to the customer. Refer to the manufacturer's instructions for each specific vehicle.

System Check

The air bag system will perform a self-diagnostic check each time the ignition is turned on. When air bags are replaced, use the following procedure to check the system. While no one is inside of the vehicle, connect the negative battery cable. Then, turn on the ignition. If the air bag light goes out after the self-diagnostic check, the system is in proper operating condition.

Summary

- Restraint systems can be classified into three groups: interior components, seat belts, and air bags.
- There are two types of active seat belts: lap belts and shoulder belts.
- Some vehicles are equipped with seat belt pretensioners, which tighten the seat belt or retractor during a collision.
- Do not replace individual parts of a seat belt; replace the entire assembly.
- Check restraint system components for damage after every collision.
- Replace any damaged restraint system parts.
- Air bags are designed to deploy during a collision of sufficient severity.
- Do not install used air bag system parts.
- Air bag deployment is dependent on a properly repaired unibody.
- Many new vehicles are equipped with side curtain air bags.
- A clock spring is used to maintain the electrical connection between the driver-side air bag module and the wiring harness.
- Read the service manual to find out what parts should be checked and replaced after air bag deployment.
- Air bags can deploy with deadly force. Observe safety precautions when handling or disabling air bag system parts.

Review Questions

Please do not write in this textbook. Place your answers on a separate sheet of paper.

1. A(n)______ contains a spool of wire that winds and unwinds as the steering wheel is turned.
2. A(n) ______ is a reinforced area of the sheet metal body.
3. The ______ contains the folded air bag and the inflater substance.
4. Rapid deceleration is detected by a(n) ______ sensor.
5. The ______ module signals the air bag to deploy during a collision.
6. The ______ locks during a collision to prevent the occupant from moving.
7. Rapid deceleration causes this sensor's roller to be thrown forward. The roller touches the electrical contacts, sending an electrical signal to the control module. This sensor is called a(n) ______ sensor.
8. Some vehicles are equipped with seat belt ______, which tighten the seat belt or retractor during a collision. The tightening either properly positions the seat occupant for air bag deployment or holds the seat occupant in place during a collision.
9. Front seat occupants do not need to wear seat belts if the vehicle has air bags. True or False?
10. Why does an air bag system have a backup power supply?
11. There are two kinds of impact sensors. An impact sensor detects rapid ______.
12. Impact sensors use a gold-covered ball or a coil spring to complete the electrical circuit and send an electrical impulse to the safing sensor. True or False?

13. All air bag systems have impact sensors mounted on the radiator support. True or False?
14. ______ air bags are designed to deploy with less force.
15. Deployed air bag modules can be reused. True or False?
16. A side impact air bag may be located in the seat back, door, or roof rail. True or False?
17. Clock spring, impact sensor, and control module should be checked after air bag deployment. True or False?
18. Explain how to test an active seat belt retractor.
19. In ______, the air bags system checks itself for problems each time the ignition is turned on.
20. Do not replace individual parts of a seat belt; replace the entire assembly. True or False?

ASE-Type Questions

1. Which of the following reels the shoulder harness in and out as needed?
   (A) Seat belt anchor.
   (B) Seat belt retractor.
   (C) Seat belt.
   (D) Track anchor.
2. A welded-in radiator support in an air bag equipped vehicle is replaced. Technician A says that the radiator support must be in the right place for proper air bag deployment. Technician B says that the radiator support must be rustproofed for proper air bag deployment. Who is right?
   (A) A only.
   (B) B only.
   (C) Both A and B.
   (D) Neither A nor B.
3. The air bags have deployed in a front-end collision. Technician A says that the impact sensors must be replaced. Technician B wants to consult the manufacturer's recommendations for what should be inspected and replaced. Who is right?
   (A) A only.
   (B) B only.
   (C) Both A and B.
   (D) Neither A nor B.
4. A clock spring shows some melting of its plastic body. Technician A wants to replace the clock spring because it shows heat damage. Technician B says that the clock spring must always be replaced after a collision whether it shows heat damage or not. Who is right?
   (A) A only.
   (B) B only.
   (C) Both A and B.
   (D) Neither A nor B.
5. A retractor does not reel the belt in and out. Technician A wants to replace the retractor. Technician B wants to replace just the belt. Who is right?
   (A) A only.
   (B) B only.
   (C) Both A and B.
   (D) Neither A nor B.
6. An active seat belt retractor needs to be tested. Technician A wants to drive the vehicle in the shop at 2–3 mph and then step on the brakes. Technician B wants to drive the vehicle about 10 mph in a parking lot and then step on the brakes. Who is right?
   (A) A only.
   (B) B only.
   (C) Both A and B.
   (D) Neither A nor B.
7. A unibody vehicle has rust weakening in the seat belt anchor area. Technician A says that the vehicle is not safe to drive. Technician B says that as long as the seat belt anchor bolt is tight, the seat belt will function properly. Who is right?
   (A) A only.
   (B) B only.
   (C) Both A and B.
   (D) Neither A nor B.
8. A seat belt has torn webbing. Technician A says that slight tears in the webbing do not cause a problem. Technician B says that the belt assembly should be replaced. Who is right?
   (A) A only.
   (B) B only.
   (C) Both A and B.
   (D) Neither A nor B.
9. Which of the following must be worn when cleaning up sodium hydroxide powder after air bag deployment?
   (A) Rubber gloves.
   (B) Safety glasses.
   (C) Dust respirator.
   (D) All of the above.
10. An air bag system is to be deactivated. Technician A disconnects the negative battery cable and immediately disconnects the impact sensors. Technician B disconnects the battery and waits thirty minutes. Who is right?
   (A) A only.
   (B) B only.
   (C) Both A and B.
   (D) Neither A nor B.

11. When a self-diagnostic air bag system detects a problem, the air bag light on the dashboard will remain illuminated or it will blink. Technician A says the light indicates that there is a Diagnostic Trouble Code (DTC) stored in the air bag control module's memory. Technician B says that after air bag deployment and before replacing any air bag system components, the technician should see which DTCs are present. Who is right?
    (A) A only.
    (B) B only.
    (C) Both A and B.
    (D) Neither A nor B.
12. Retrieving the Diagnostic Trouble Code (DTC) will tell the technician where the fault is in a self-diagnostic air bag system. Technician A says DTCs are retrieved with a scan tool. Technician B says a scan tool can determine if both charges in a two-stage air bag have fired. Who is right?
    (A) A only.
    (B) B only.
    (C) Both A and B.
    (D) Neither A nor B.
13. A new clock spring must be installed. Technician A wants to position the steering wheel so that the front wheels are pointing straight ahead. Technician B wants to remove the driver-side air bag module first. Who is right?
    (A) A only.
    (B) B only.
    (C) Both A and B.
    (D) Neither A nor B.
14. When replacing an impact sensor, the arrow should point ______.
    (A) rearward
    (B) forward
    (C) towards the safing sensor
    (D) towards the other impact sensor
15. An undeployed air bag module is put on a workbench. It should be placed ______.
    (A) face up
    (B) face down
    (C) on its side
    (D) in a box

Section 5

Refinishing

Chapter 24. Refinishing Tools and Equipment
Chapter 25. Refinish Materials
Chapter 26. Paint Mixing and Reducing
Chapter 27. Spray Technique
Chapter 28. Surface Preparation
Chapter 29. Color Matching
Chapter 30. Paint Application
Chapter 31. Specialty Painting
Chapter 32. Detailing

Chapter 24

Refinishing Tools and Equipment

Objectives

After studying this chapter, you will be able to:

- Identify hand and power tools used during refinishing operations.
- Identify the types of spray guns.
- Describe the various types of spray booths: cross-draft, semi-downdraft and downdraft.
- Identify equipment used during refinishing operations.
- Name the parts of a compressed air system.

Technical Terms

air cap
air compressor
air hose
air makeup unit
air regulator
atomization
baking
basement full downdraft spray booth
blasting equipment
block sanding
blowgun
buffer
condensate
cross-draft spray booth
desicant dryer
discharge air pressure
drive-through spray booth
exhaust fan
finish dual-action sander
fluid tip
full downdraft spray booth
hazardous waste
heat gun
infrared lamps
infrared thermometer
masking equipment
negative pressure movement
offspray
overspray
paint mixing room
paint shaker
painting platform
panel positioner
piston air compressors
pit full downdraft spray booth
positive pressure movement
powder coating system
prep station
pressure relief valves
pressure washer
recycling air system
refrigerator dryer
rotary screw air compressors
rough DA sander
sanding block
sanding pad
sanding pen
sanding stick
semi-downdraft spray booth
side downdraft spray booth
side-load spray booth
single-stage piston air compressor
solvent recycler
spray booth
spray guns
spray gun cleaner
two-stage piston air compressor
UV dryers
vacuum system

Introduction

Automotive refinishing requires many specialized tools, as well as many common hand and power tools. This chapter describes the tools and equipment most commonly used by the paint technician. A thorough knowledge of refinishing tools and equipment will help make you a more productive technician.

Hand Tools

A variety of hand tools are used during refinishing. These include sanding tools, removal tools, and tools used to apply paint and other finishes. In most cases, the technician owns the hand tools described in this section.

Sanding Tools

Hand sanding is a common task in refinishing. The sanding tools are used not only to abrade but also to level the surface. Sanding the surface to level out irregularities is called ***block sanding***. The biggest problem with hand sanding is that the technician's finger pressure tends to dig grooves into the paint, **Figure 24-1**, leading to an uneven surface. To prevent this problem, a sanding block or sanding pad should be used. A ***sanding block*** is rigid and is used to sand a surface level. A ***sanding pad*** is softer than a block and is used to give sandpaper a firm, yet pliable base of support.

Three types of sanding pads are shown in **Figure 24-2**. Sandpaper is wrapped around these pads to ensure that the entire surface of the sandpaper will contact the panel. The pad in the center can only be used dry. The other two pads can be used wet or dry. The pad on the left is harder than the pad on the right. A hard pad does not easily bend, so it can be held flat to block sand a low-crown panel. Used on edge, the hard pad can be used to block sand a high-crown area. A soft pad readily conforms to any contour and works best when sanding a surface that is already level, such as an undamaged replacement part, or an area that has already been block sanded, such as a repaired dent.

The sanding block shown in **Figure 24-3** features internal spikes designed to grip and hold sandpaper firmly in place. Sandpaper is wrapped around the front and rear edges of the block and pressed into the spikes. The paper must be tight on the block. If not, it will slide, flex, and tear while sanding. This type of sanding block is available in 5" and 9" lengths. This hard rubber block does not readily conform to surface contours. However, it can be used on edge to sand a high-crown surface.

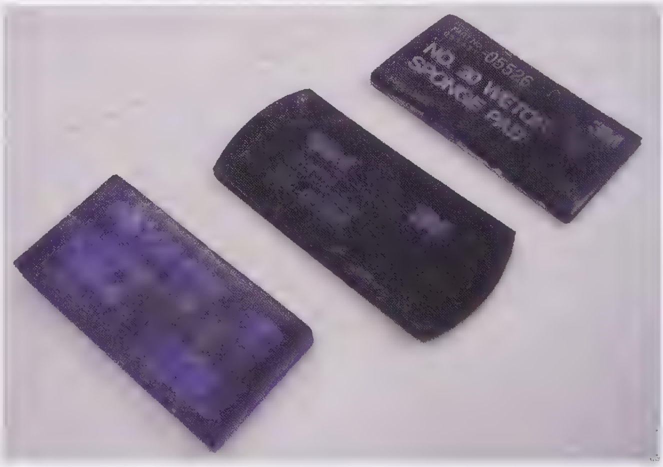


Figure 24-2. *Sanding pads eliminate uneven hand sanding pressure.*

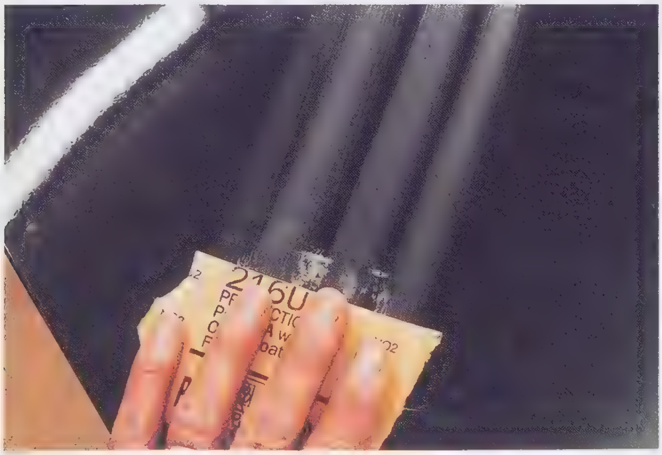


Figure 24-1. *Fingers will dig grooves into the paint when hand sanding without a sanding block or pad.*

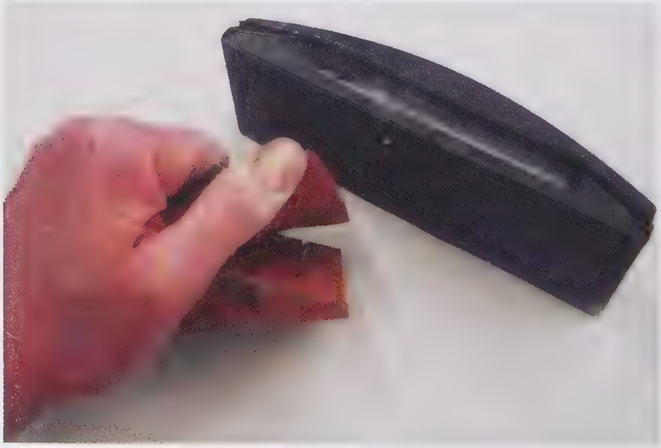


Figure 24-3. *The spikes inside the sanding block hold the sandpaper firmly in place.*

The sanding blocks shown in **Figure 24-4** use a special type of dry sandpaper. The block shown in **Figure 24-4A** uses Velcro-backed sandpaper. The block shown in **Figure 24-4B** uses an adhesive-backed paper. Both are available in 4" and 7" lengths, as well as a 17" long board version. These sanding blocks do not bend to match the contour of the panel.

A conformable sanding block is shown in **Figure 24-5**. This block can bend in one direction only. Removable rods allow the degree of bend to be adjusted. With all rods in place, the block is at the maximum rigidity. With all rods removed, the block is the most conformable. This sander has a metal shoe on which the self-adhesive sandpaper is mounted. Do not bend the block unless it is placed against a surface. Flexing the block without support from an underlying surface will bend the metal shoe and ruin the sander.

Flexible sanding blocks are shown in **Figure 24-6**. These blocks are rigid enough to block sand but flexible enough to conform to surface contours. Self-adhesive sandpaper can be attached to the blocks.

The block on the left has a tear-shaped cross section. The rounded end of the block is used to sand concave areas, while the sharp end fits into recessed body lines. To its right is a cylindrical block, which is ideal for working a small-radius concave area. The third block in the photo is a wide rectangular block typically used on low-crown areas, while the narrow rectangular block on the far right is designed for effectively sanding a double-crown surface, such as a motorcycle tank. The block can bend because it is narrow. Bending allows the block to conform to the shape of the tank.

Although blocks are flexible, sandpaper is not, and this can be a problem. Bending a block will cause the sandpaper on the bottom of the block to bunch up, while sandpaper on the top of the block will have a tendency to stretch and tear.

A ***sanding stick***, **Figure 24-7**, is another tool for finish block sanding. Because there is no deflection in the surface of the stick, block sanding with a sanding stick produces a level surface. To make a sanding stick,

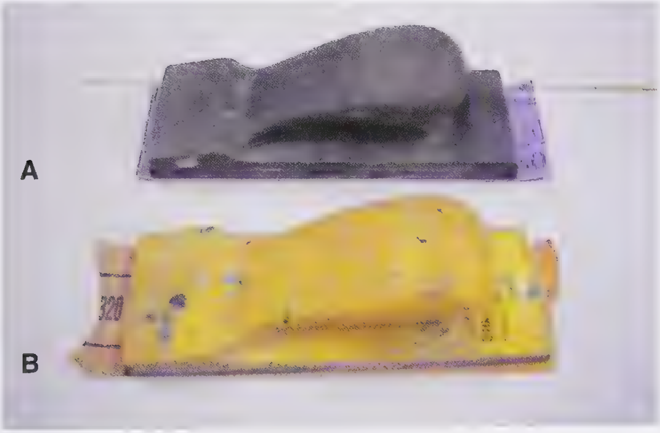


Figure 24-4. *A—This block can only use Velcro-backed sandpaper. B—This block uses adhesive-backed sandpaper.*

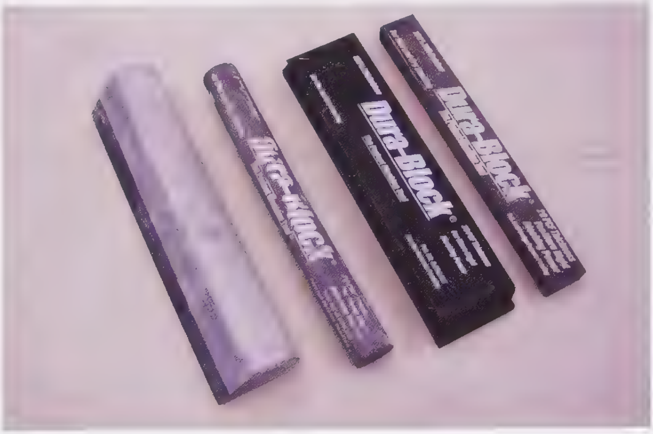


Figure 24-6. *These sanding blocks can bend slightly to conform to various panel shapes.*

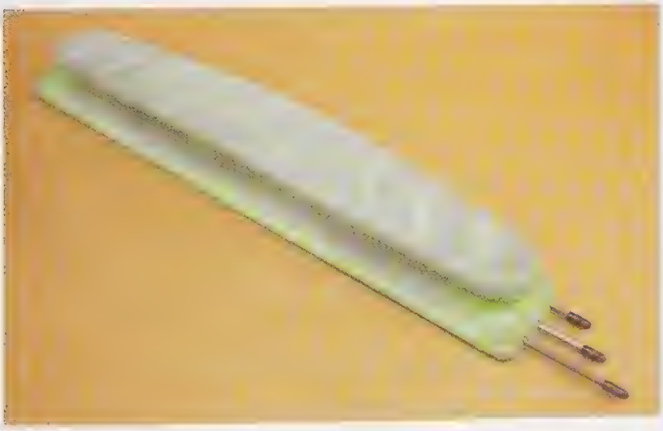


Figure 24-5. *Removing the rods changes the rigidity of this flexible sanding block.*

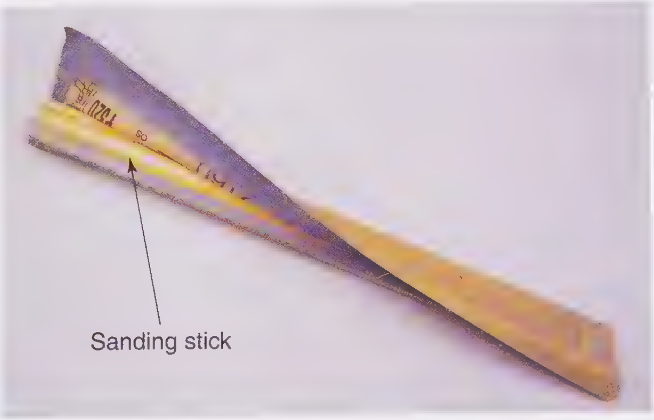


Figure 24-7. *A sanding stick has no give so it produces a flat, level surface when block sanding.*

simply attach self-adhesive sandpaper to a stir stick or paint paddle. Choose a stick that is flat, with no arch.

The ***sanding pen*** is designed to reach into small, difficult-to-access areas. Rubbing the tip over the existing paint abrades the surface, allowing adhesion of the refinish paint. Bundled strands of fiberglass are the "heart" of a sanding pen. Use quickly wears down these fibers. However, twisting the collar on the pen pushes out more of these sharp, abrasive fibers.

Wet sanding requires an ample supply of water to keep the work surface lubricated and to wash away sandpaper-clogging residue. Sandpaper suitable for wet sanding is soaked in water before use. The sandpaper is then wrapped around a sanding pad. Some refinish technicians use a sponge and a bucket of water when wet sanding. The sponge is dipped into the water and then squeezed to apply additional water to the surface. Another way to supply water is for the technician to squirt water from a squeeze bottle onto the work surface. Also available are clever devices that hook up to a water hose to drizzle a small but continuous stream of water over the sanding surface.

WORKING SMART

Residue buildup created during wet sanding can impair the technician's ability to see the work surface and accurately gauge progress. However, unwanted residue is easily removed with a thin, hard rubber block called a squeegee. Wiping the squeegee over the wet surface effectively removes the water and sanding residue.

Removal Tools

If the shop is organized into separate body and paint departments, the body technician will perform most disassembly and reassembly. Nevertheless, some minor disassembly may still be necessary after the vehicle enters the paint shop. A productive paint technician will have the tools to perform minor removal. See **Figure 24-8**. These tools include a deep well 1/4"-drive metric socket set with ratchet, a razor blade scraper, a plastic stick called a *bone*, a putty knife, a plastic rivet removal tool called a *crow's foot*, a Torx driver set, and a Phillips screwdriver.

When removing parts, always protect the paint from accidental damage. Scratching or chipping the paint creates extra work.

Application Tools

Application tools are used to apply sealer, undercoat, and touch-up paint.

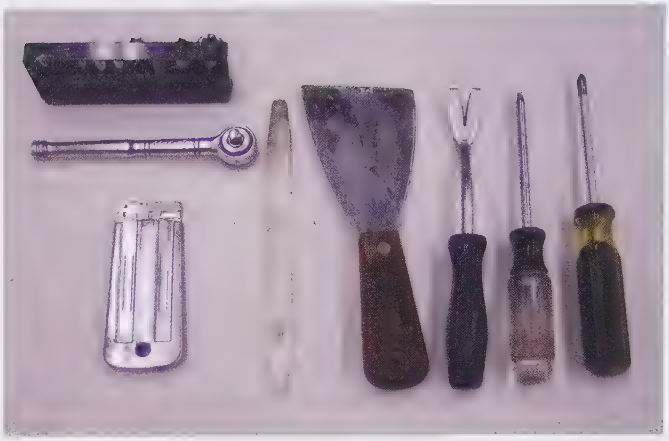


Figure 24-8. *These tools are used to remove many small obstructions from a vehicle: 1/4"-drive socket set, razor blade scraper, plastic stick, putty knife, crow's foot, Torx driver, and Phillips screwdriver.*

A roller system is used to apply undercoat to a featheredged area. It consists of a roller holder, a tray, and a sponge roller. See **Figure 24-9**. Even though undercoats must be mixed differently for roller application, the use of a roller eliminates the need for masking, spraying, and spray gun cleaning, significantly reducing preparation time for small repairs. If the roller tray is lined with aluminum foil and the sponge roller is discarded after use, the clean up of the roller system is minimal. A rolled undercoat will have a rougher surface than a sprayed undercoat. The rougher undercoat requires extra time to sand smooth prior to painting.

Small "artist" paintbrushes can be useful in automotive refinishing. Often, the existing paint on a panel will be sprayed with clearcoat only. Any defects, such as chips or scratches in the existing paint, would be visible through the clearcoat. Paint that matches the color of

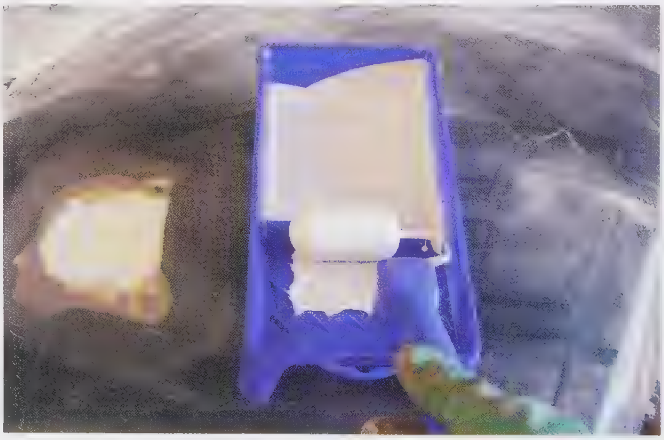


Figure 24-9. *Roll-on primer application requires a roller, roller holder, and tray.*

the vehicle is carefully applied with a small paintbrush to eliminate the defects before clearcoat is applied.

Some seam sealers can be spread with a paintbrush, but typically caulking guns are used to apply seam sealer prior to painting. Seam sealer is available in one-part and two-part varieties. A standard caulking gun is used to apply some one-part sealers. Two-part seam sealer is packaged in side-by-side tubes and is dispensed through a special two-ram gun. The two parts are thoroughly mixed as they are pushed through the gun's nozzle. Most manufacturers recommend that the first 6" of mixed material be discarded.

A pump bottle can be used to dispense cleaning solvent. Pumping the plunger pressurizes the liquid and pressing the trigger releases the solvent until the pressure is dissipated. Pumping the plunger repressurizes the solvent in the bottle.

Power Tools

The following power tools are used to speed up refinishing jobs. Many of the tasks performed today with power tools were done by hand in the past. Power tools make the jobs faster and easier, making the technician much more productive.

Sanding Tools

A ***finish dual-action sander***, or finish DA sander, spins a sanding disk in an oscillating pattern, resulting in a smooth sanding action. See **Figure 24-10**. Another type of DA sander, a ***rough DA sander***, can be used as a grinder or as a DA sander, **Figure 24-11**. To switch from sanding to grinding, the sander's shaft is locked in place. This eliminates the oscillating action, leaving only rotation of the pad. (Using the rough DA sander in this mode is best suited for rough sanding rather than finish sanding as this is a grinding mode.)

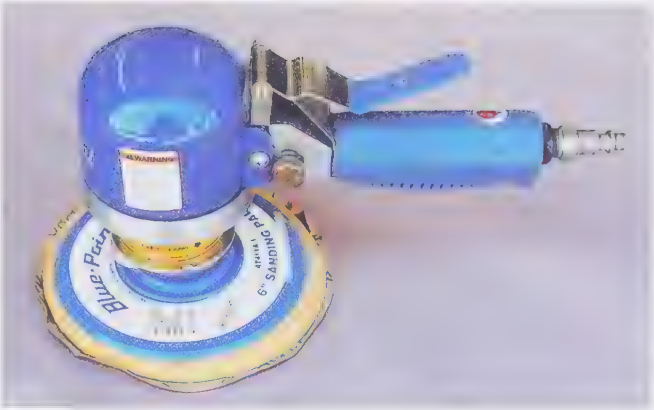


Figure 24-11. *A rough DA sander can be set to rotate as a grinder or as a DA sander.*

DA sanders accept sandpaper disks that are available in a wide variety of grits. Both types use a pad to mount a sandpaper disk. The pad, which can be 5" or 6" in diameter, will have either a Velcro face or a smooth face. The Velcro face is exclusively for Velcro-backed sandpaper disks, while the smooth face is for adhesive-backed sandpaper disks.

Adhesive-backed disks are single-use products. Once they are removed from the pad, they cannot be reinstalled. A disk installed on a dirty pad will not adhere securely and will fly off as the pad spins, so the pad must be kept clean. Velcro-backed disks can be reused.

A jitterbug sander is shown in **Figure 24-12**. This sander uses sandpaper sheets that are held in place by clips. Depending on the grit of paper installed, this oscillating sander can be used for rough sanding or finish sanding. The jitterbug also can be used wet or dry.

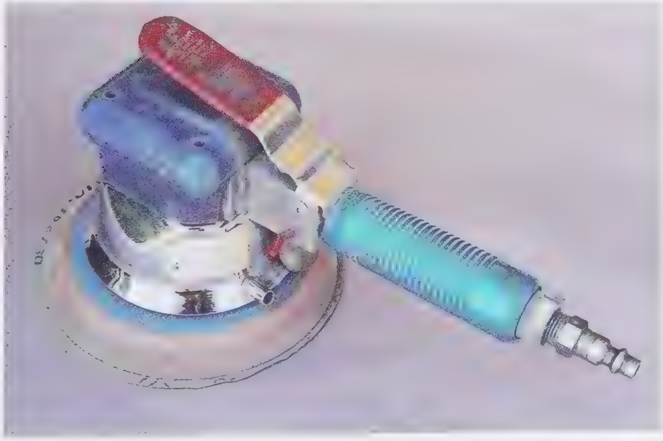


Figure 24-10. *A finish DA sander creates a smooth surface.*

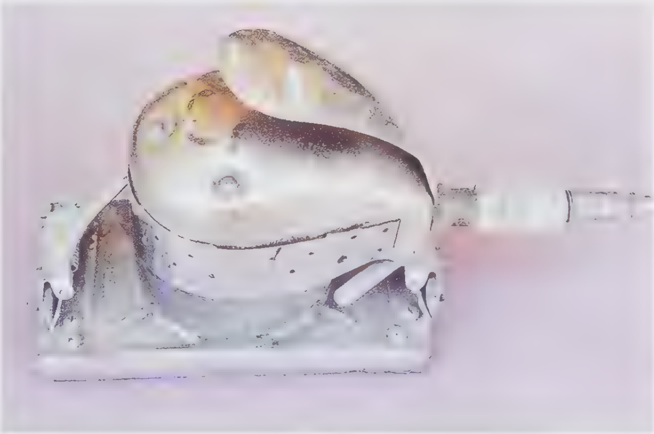


Figure 24-12. *A jitterbug sander has a rectangular pad and can be used wet or dry.*

Both DA sanders and jitterbug sanders are equipped with a trigger or dial to regulate sanding speed. As with all air tools, the DA and jitterbug should have two drops of air tool oil added before each day of use.

The pad installed on the DA or jitterbug should be matched to the job. To make a level cut when sanding, a firm pad is desirable. For featheredging, a soft pad is required. A soft pad makes a wider, flatter featheredge. When sanding clearcoat for a blend, a soft intermediate pad can be installed between the sandpaper and the pad.

DA sanders are much more popular than jitterbug sanders. More types of pads are available for DAs than jitterbugs, and sanding disk replacement is faster.

Blow Gun

A good paint job requires a clean vehicle. A ***blowgun*** uses air pressure to remove dust and moisture from the vehicle, and is considered the paint technician's best tool for cleaning a vehicle before painting. Pulling the trigger on the blowgun opens a valve, releasing a jet of high-pressure air. Aiming the airstream at panel gaps and openings will drive out moisture and sanding dust.

Buffers

A ***buffer*** spins a wool or foam pad over a painted surface to rapidly remove surface imperfections and polish the paint to a high gloss. An electric buffer is shown in **Figure 24-13**. This buffer is equipped with a rotation speed dial to set the desired pad rotation speed. When the buffer's trigger is pulled, the pad spins at the set speed. Some electric buffers have a single speed—no variation is possible.

To maintain an electric buffer, make sure the cord is in good condition. A frayed cord is dangerous. Also, when using a wool pad, the lint that falls off the pad during buffing may accumulate in the buffer's cooling fan air intake. Periodically remove any lint from this air intake.

A pneumatic (air-powered) buffer is shown in **Figure 24-14**. The speed of pad rotation is controlled by regulating air pressure. Increasing air pressure causes the pad to rotate at a faster speed. A pneumatic buffer is less powerful than an electric buffer.

Removal Tools

An air chisel fitted with a molding-removal blade takes advantage of the tool's up-and-down hammering action to quickly remove body moldings. An air-powered or electric drill can be used to spin a wire wheel or plastic abrasive wheel. A drill can also be used to spin a stripe eraser. The stripe eraser is a rubber wheel that will rub off a tape stripe or decal without harming the underlying paint.

A small angle grinder is useful in confined areas. The grinder spins a two-inch or three-inch diameter abrasive pad. The small size of the pad allows the angle grinder to fit into areas a full-size grinder cannot reach.

Heat Gun

A ***heat gun*** will help in the removal of moldings and decals. Be careful with a heat gun because it can easily produce enough heat to cause paint to blister and bubble. A shutter on the body of the gun regulates the amount of heat discharged from the nozzle.

Spray Guns

Spray guns use air pressure to break liquid paint into tiny droplets, creating a sprayable mist. The process of breaking up a liquid into tiny droplets is called ***atomization***. Spray guns are classified by the volume and pressure of air used to atomize paint. A conventional spray gun atomizes with air at relatively high pressures (30–60 psi). If 40 psi of air is delivered to the inlet

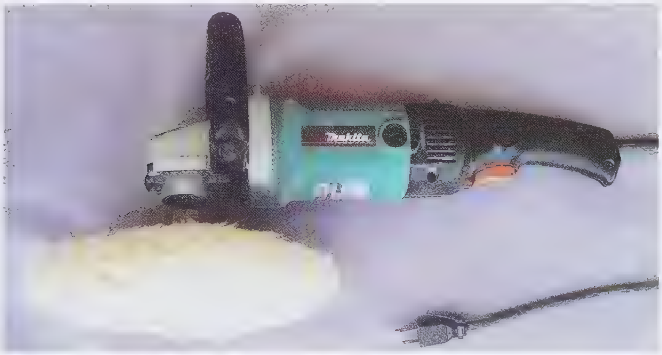


Figure 24-13. *The operator controls the rpm on this electric buffer.*

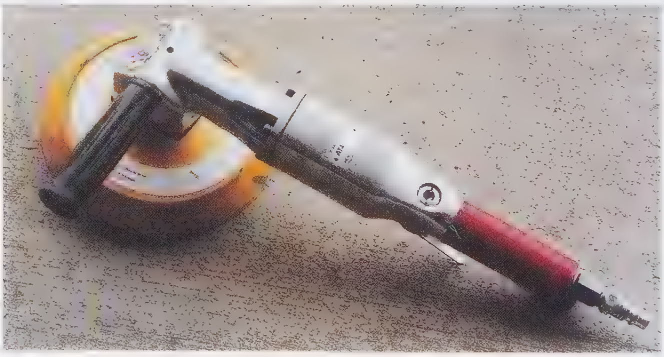


Figure 24-14. *A pneumatic buffer weighs less than an electric buffer.*

of the spray gun, the gun will discharge about 40 psi of air. At this pressure, much of the paint is blown past the target or bounces back at the painter. Paint blown past the target is called ***overspray***. Paint that bounces back at the technician is known as ***offspray***.

High-volume, low-pressure (HVLP) spray guns are designed to diminish overspray and offspray, minimize paint usage, and reduce air pollution. HVLP spray guns are designed for greater transfer efficiency than conventional spray guns. The transfer efficiency of a spray gun is calculated by dividing the amount of solids deposited by the amount of solids in the sprayed paint. An HVLP spray gun uses a large volume of air at low pressure, less than 10 psi discharge pressure, to atomize paint. A low-volume, low-pressure (LVLP) spray gun also reduces overspray and offspray, atomizing paint with a low volume of air and discharging low-pressure air. A LVLP spray gun can be used with an air compressor that has less capacity, measured in cubic feet of compressed air discharged per minute, than an HVLP spray gun.

Siphon-Feed Spray Gun

A siphon-feed spray gun is shown in **Figure 24-15**. The paint cup, which holds the paint, is located below the gun. A paint tube extends from the gun into the paint cup. High-pressure air passes over this tube and creates a vacuum powerful enough to draw (siphon) paint into the gun and out through the air cap. The high pressure is necessary because liquid paint is heavy and viscous. Unfortunately, this high pressure is what reduces the transfer efficiency of a siphon-feed spray gun.

A vent hole in the cup's lid allows air to enter the cup to displace the paint as it is drawn out. Paint will not flow through the gun if the vent hole is clogged. A diaphragm is used to keep paint from leaking from the vent hole when the gun is tilted. See **Figure 24-16**. The hole in the diaphragm is located opposite the vent hole in the lid.

The paint gun lid threads onto the cup, or it is held in place on the cup by a locking mechanism. See **Figure 24-17**. A gasket between the lid and the cup helps prevent leaks. The paint cup for a siphon-feed gun can be made of plastic, but aluminum cups are more common.

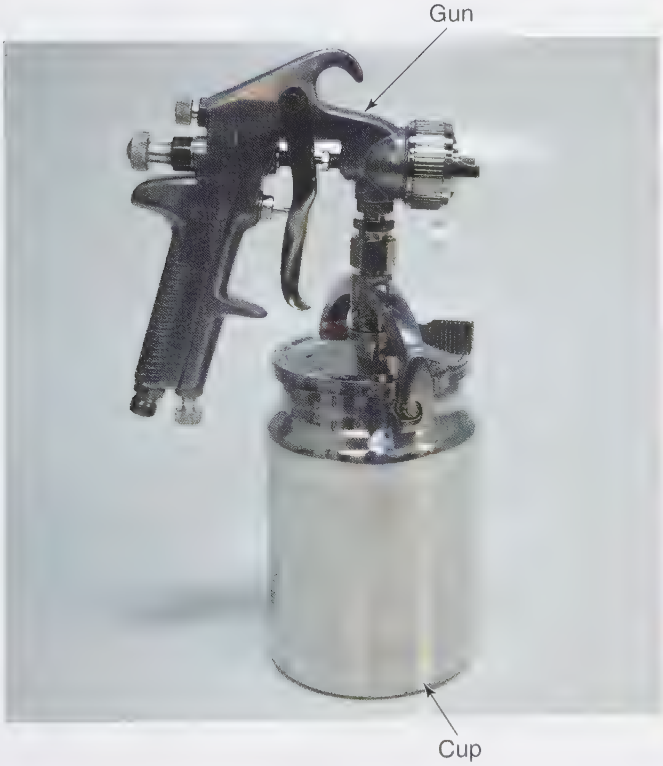


Figure 24-15. *A siphon-feed spray gun pulls the paint up and out of the cup.*

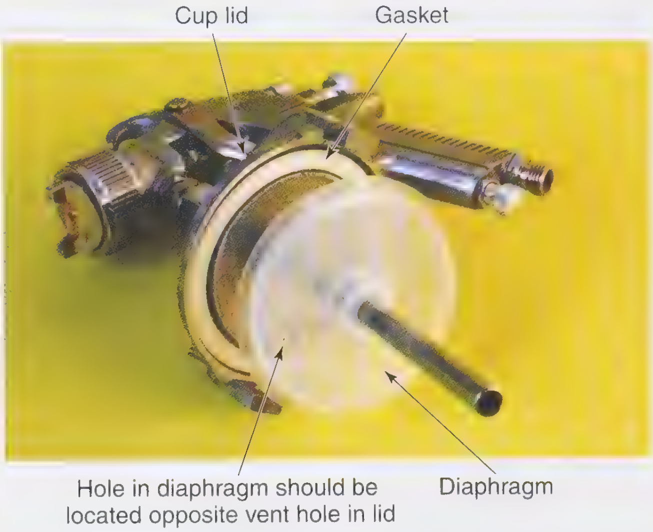

Cup lid
Gasket
Hole in diaphragm should be located opposite vent hole in lid
Diaphragm

Figure 24-16. *A leaking cup is a messy problem. This gasket keeps the paint in the cup.*

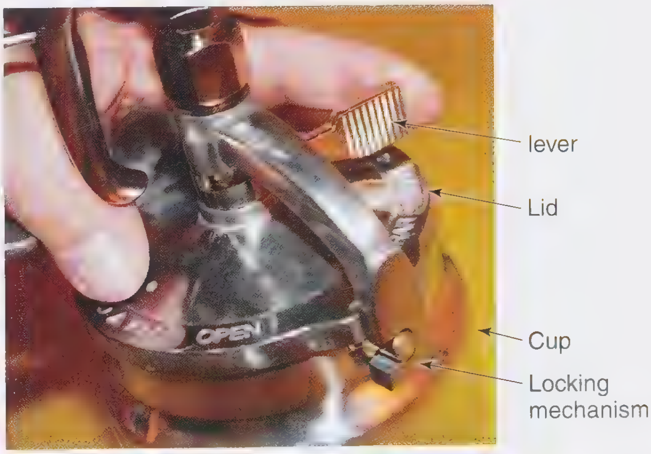


Figure 24-17. *This paint cup lid is held to the cup with a locking mechanism that is tightened or loosened by moving a lever.*

Note that there are two distinct passageways in the cutaway of a siphon-feed spray gun shown in **Figure 24-18**. One passageway is for pressurized air, and the other is for paint. Pulling the spray gun trigger halfway opens the air valve allowing a stream of compressed air to flow through the air passageway. When just the air valve is open, compressed air flows from the air inlet to the ***air cap***. The airstream exits from three different locations in the air cap: the center orifice, the side orifices, and the auxiliary orifices. See **Figure 24-19**. An air baffle distributes the air so the correct amount of air is available at each air cap opening.

Pulling the trigger all the way back moves the needle out of the fluid tip. The ***fluid tip*** contains a porthole that allows the paint, sometimes called fluid or material, to exit the spray gun. The fluid tip and the needle are a matched set. They are machined for a precise fit.

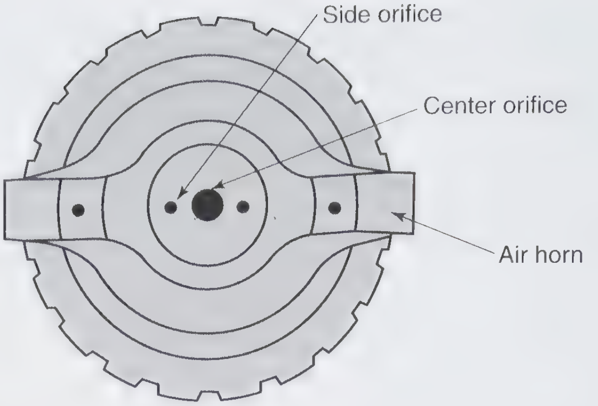


Figure 24-19. *The air discharged from the center orifice and auxiliary orifices atomizes the paint. The air from the side orifices sets the shape of the fan or spray pattern.*

NOTE

When spraying paint, always pull the trigger until it cannot move back any farther.

The air streaming from the center orifice of the air cap contacts the paint first. The air from the center orifice atomizes the liquid paint, breaking it up into a spray mist of droplets. Next, the air from the auxiliary orifices hits the spray mist, further breaking down the droplets into an even finer mist. A third stream of compressed air, from the side orifices, contacts the fine spray mist and changes its shape, or pattern. Note that the paint and the air do not mix inside the gun. Instead, the mixing of air and paint takes place outside the air cap.

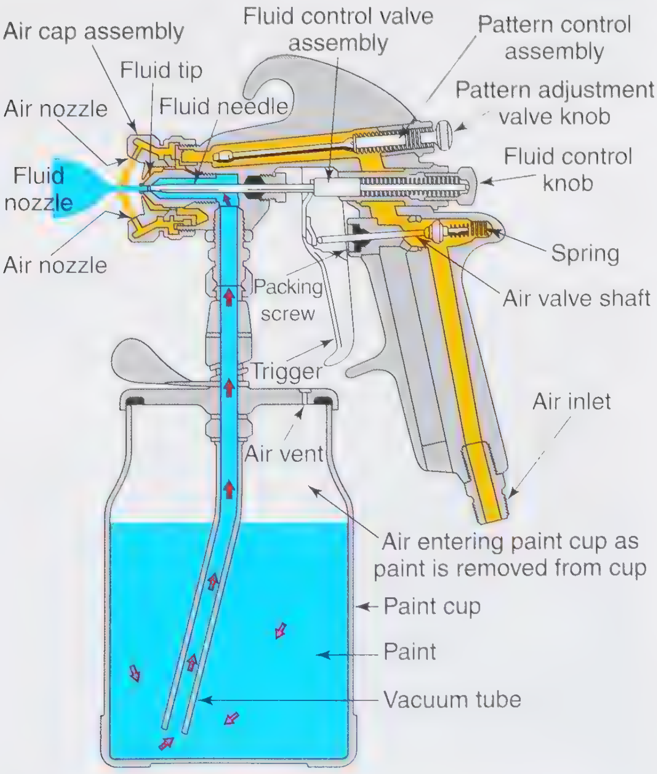


Figure 24-18. *This cutaway shows how air and paint flow through a siphon-feed spray gun.*

A correct ratio of air and paint is required for proper atomization. The fan knob and the fluid control knob allow you to adjust the spray gun to achieve the desired ratio and spray pattern. The fan knob, or pattern control knob, regulates the amount of air that flows through the side orifices. The fluid control knob regulates the amount of paint discharged through the fluid tip. The location of the knobs is the same for all manufacturers.

Fluid tips are classified by the size of the fluid tip hole. The size of the hole in the fluid tip determines the amount of paint that can flow out of the spray gun in a given amount of time. Fluid tip sizes range from 1.2 mm to 2.2 mm. Paint and spray gun manufacturers recommend the size of the fluid tip for a specific spray gun spraying a specific type of paint. In general, high-solids topcoats (basecoats and clearcoats) require a smaller fluid tip than non-high-solids paint. Because high-solids paints are thicker than non-high-solids paints, they require more atomization air to produce a smooth paint finish. However, increasing air pressure is not an option with HVLP spray guns. Therefore, a smaller fluid tip must be used on HVLP guns to reduce the amount of paint to a level that can be effectively atomized by the available air. However, the fluid tip must not be too small, as some high-solids paint is too thick to readily move through a small hole.

A large fluid tip will apply more paint than a small tip. For undercoats, where atomization for a smooth surface is less important, the fluid tip may be larger.

Gravity-Feed Spray Gun

Paint is held in a cup located above the air cap in a gravity-feed spray gun. Pulling the gun's trigger allows the paint to flow down, by gravity, to the air cap. A gravity-feed spray gun is shown in **Figure 24-20**. Fan knob and fluid control knob placement varies. Different brands of spray guns may have the knobs in different locations.

Gravity-feed spray guns have either a plastic or aluminum cup, **Figure 24-21**. Plastic cups may feature a screw-on lid. The threads of the cup and lid must be kept clean. If the threads are caked with dried paint, the lid cannot seal properly and will leak. Aluminum cups usually have a friction-fit lid that snaps into place. Both types of lids have a vent hole that must be kept free of obstructions.

The system shown in **Figure 24-22** consists of a disposable cup liner and lid, and a reusable cup. After the paint is mixed in the cup liner, the lid, which contains a filter, is installed and the cup system is snapped into the adapter on the gravity-feed spray gun. The filter removes dirt or bits of debris that may be present in the paint.

The air line is attached to the spray gun and the gun is triggered. This collapses the disposable cup liner. The paint is now ready to spray. This system allows a gravity-feed spray gun to be held upside down during spraying without leaking. Additionally, spray gun cleanup is minimized because only the air cap area of the gun, the area where the paint flowed through, requires cleaning.

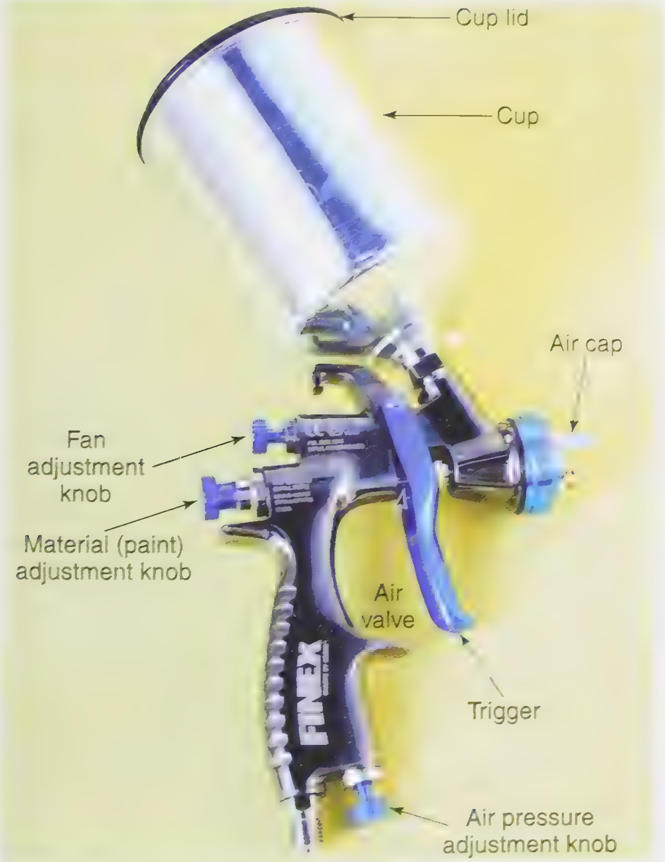

Cup lid
Cup
Air cap
Fan adjustment knob
Material (paint) adjustment knob
Air valve
Trigger
Air pressure adjustment knob

Figure 24-20. *The paint cup is above the paint discharge outlet in a gravity-feed spray gun.*

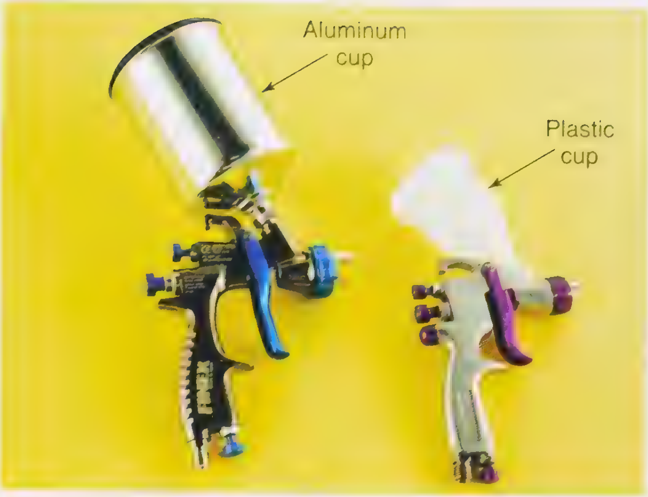


Figure 24-21. *Plastic or aluminum cups hold the paint in a gravity-feed spray gun.*

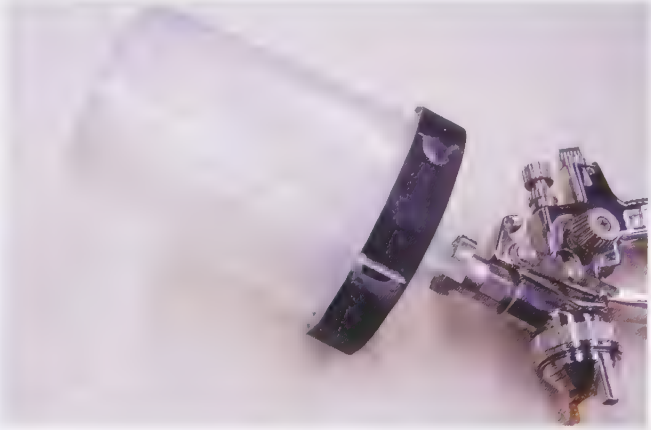


Figure 24-22. *This disposable paint cup liner system changes the spray characteristics of a gravity-feed spray gun. The cup cannot leak and the spray gun will operate upside down.*

NOTE

Some gravity-feed and siphon-feed HVLP spray guns have a pressurized cup. The greater-than-atmospheric pressure inside the cup helps push the paint to the air cap.

Figure 24-23 shows a gravity-feed spray gun on a workbench. It is top-heavy and easily tipped over. To prevent spills, use a holder as shown in **Figure 24-24**.

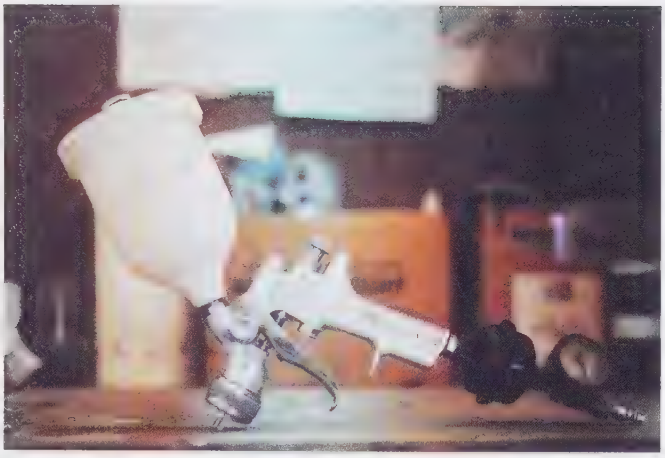


Figure 24-23. *Gravity-feed spray guns are not stable and may tip if they are set on a workbench.*

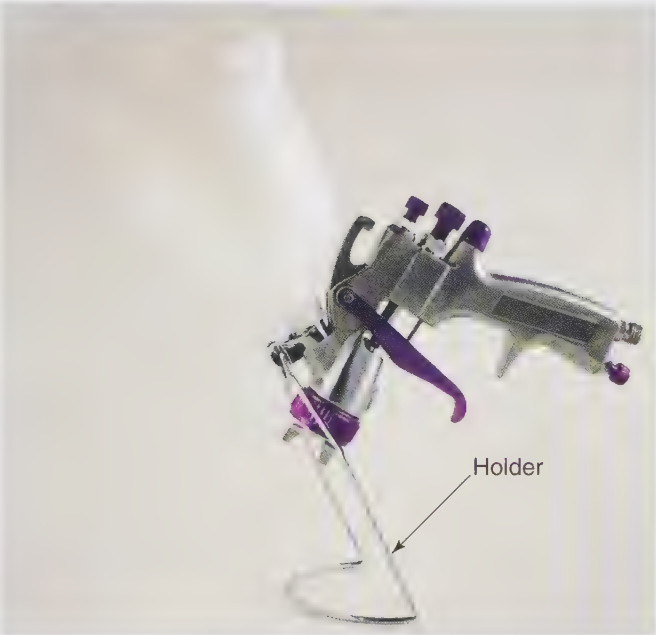


Figure 24-24. *A holder is the best way to prevent the gravity-feed spray gun from tipping over.*

Pressure-Feed Spray Gun

In a pressure-feed system, the cup is pressurized. The paint cup for a pressure-feed spray gun is called a pressure pot and can be placed several feet from the spray gun. Air pressure in the pressure pot pushes the paint to the spray gun. The pressure pot can vary in size from two quarts to five gallons. Pressure-feed spray guns are designed to spray the large amount of material needed when painting larger vehicles such as a bus or truck. By eliminating the need to have a paint cup on the spray gun, the pressure-feed spray gun is much lighter than a siphon-feed or gravity-feed gun.

There are two hoses leading to a pressure-feed gun—an air hose and a paint hose. When the pressure-feed spray gun trigger is pulled, the paint is pushed through the paint hose to the air cap. The pressure pot does not need a vent hole because it is pressurized.

A pressure-feed spray gun and pressure pot system is shown in **Figure 24-25**.

Touch-Up Spray Gun

Smaller than conventional spray guns, touch-up spray guns are used to apply paint to small or confined areas, such as the recessed area of a plastic bumper cover. Touch-up guns can be gravity- or siphon-feed. See **Figure 24-26**. Touch-up spray guns adjust and function in the same way as a full-size spray gun, but they do not feature as much paint storage capacity. Used car reconditioners often use touch-up guns on jobs such as repairs to rock chips, repaired dents, or small scratches.

Air Brush

An air brush sprays an even smaller area than a touch-up spray gun. They are often used to make artistic designs on panels. Air brushes may be siphon-feed or gravity-feed designs. The fan can be adjusted from a narrow line to about a 1" pattern. Although an air brush atomizes paint like a spray gun, there are differences in design that make some air brushes very different from spray guns.

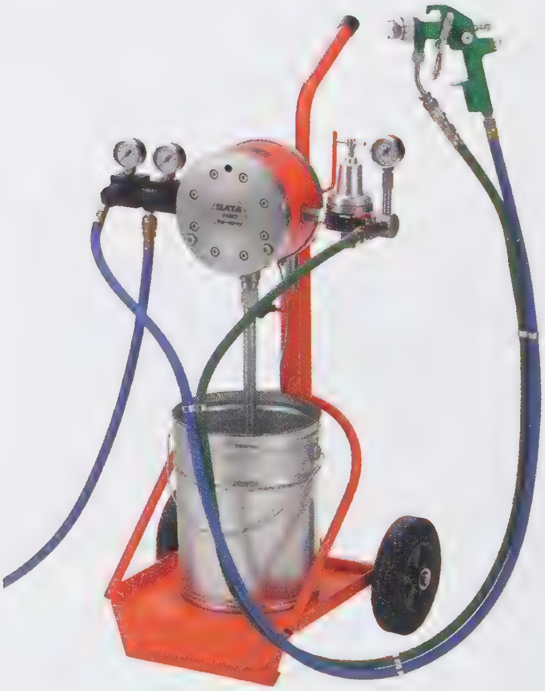


Figure 24-25. *This pressure-feed spray gun system uses a multi-gallon pressure pot.*

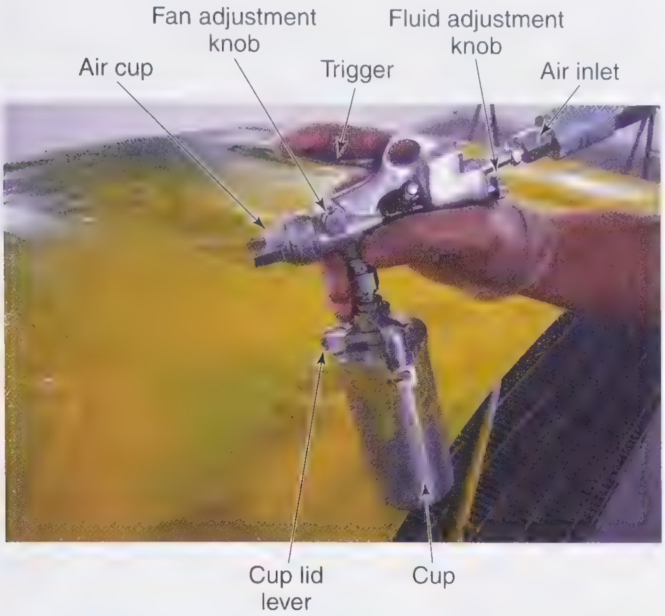

Fan adjustment knob
Fluid adjustment knob
Air cup
Trigger
Air inlet
Cup lid lever
Cup

Figure 24-26. *This siphon-feed touch-up gun is being used to spray a custom paint effect.*

One style of air brush uses a single button on the top of the gun to control both material flow and air pressure. See **Figure 24-27**. Pressing the button regulates how much atomizing air moves through the air brush; pulling the same button back regulates how much paint is released into the atomizing air. Considerable practice is required to master this type of air brush. Another type of air brush has a knob to set the amount of paint that meets the air. A trigger or button controls the amount of air discharged by the air brush.

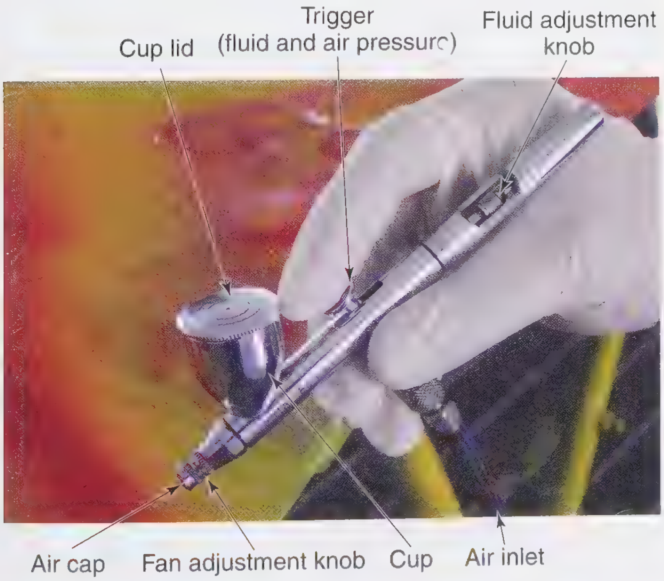

Trigger (fluid and air pressure)
Fluid adjustment knob
Cup lid
Air cap
Fan adjustment knob
Cup
Air inlet

Figure 24-27. *A gravity-feed air brush can be set to a very narrow, 1/4" wide fan.*

Undercoat Gun

An undercoat gun does not really atomize the paint. Instead, it just blows the paint out of the gun, **Figure 24-28**. The undercoat gun consists of a gun body, cup, and wand. Compressed air moving through the gun body will siphon paint out of the cup and push it through the wand. The wand is a steel tube or a plastic hose that allows the paint to be applied to an enclosed area, or a difficult-to-reach panel, such as inside a unibody frame rail. The paint is applied by inserting the wand as deep into the area as required and manually rotating the wand while slowly pulling it out.

Refinishing Equipment

Typical refinishing equipment includes spray booths, prep stations, paint mixing rooms, paint dryers, spray gun cleaners, vacuum systems, and compressed air systems. This type of equipment represents a considerable investment; therefore, it must be cared for properly.

Spray Booths

A ***spray booth*** is an enclosed area in which vehicles are painted. It is designed to remove dangerous paint mist from the surrounding air and protect the wet paint from outside contamination.

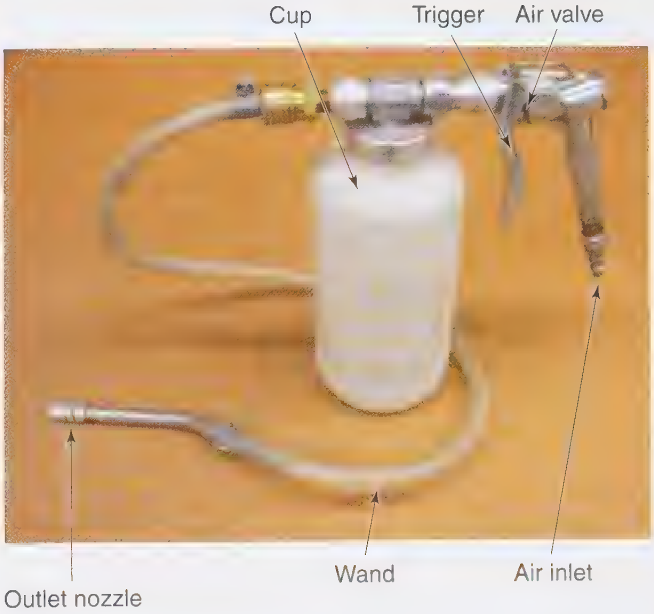

Cup
Trigger
Air valve
Outlet nozzle
Wand
Air inlet

Figure 24-28. *An undercoat gun can spray paint into hard-to-reach areas such as inside enclosed panels The paint is discharged at the nozzle of the flexible wand.*

Paint mist is made up of hazardous chemicals. A technician should not be exposed to high concentrations of these chemicals. Paint mist is also explosive. If the paint mist concentration in the air were high enough, a spark could cause a serious accident. By removing the paint mist from the air, the spray booth reduces danger to the technician.

Contaminants in the air can settle into wet paint and ruin a paint job. An enclosed spray booth protects wet paint from outside contaminants. If the vehicle were sprayed in the open shop, contaminants from other areas of the shop could drift into the wet paint.

The parts of a typical spray booth are shown in **Figure 24-29**. All spray booths have the following basic parts:

- Intake filters—Clean the air before it enters the spray booth.
- Exhaust filters—Remove dried paint before mist-laden air exits the spray booth.
- Fan or fans—Move air in through the intake filters and out through the exhaust filters.
- Exhaust stack—Directs exhaust air out and away from the shop.
- Cabin—Enclosed area made of steel panels. The cabin must be airtight.
- Man door—Door through which technicians can enter/exit the cabin.
- Entrance door—Door through which vehicles can be moved in and out of the spray booth.
- Lighting—Illuminates the cabin. Must be explosion-proof if inside the cabin. May be located outside the cabin, behind safety glass windows.
- Switches—Control fan and lights from inside booth. Must be explosion-proof.

All spray booths use fans to move air. In the simplest type of booth, an ***exhaust fan*** pulls air in from outside the booth through intake filters, draws the air around the vehicle, and forces it out through exhaust filters, discharging the air outside the building. This is called ***negative pressure movement***. If the spray booth is completely airtight, the only way the air could move into the booth would be through the intake filters. Unfortunately, spray booths are generally not airtight. Therefore, air may be pulled into the cabin through gaps in the walls or around doors. This unfiltered air contains dust from nearby repair operations.

Some spray booths have both an exhaust fan and an intake fan. The intake fan forces slightly more air into the booth than the exhaust fan pulls out. This is known as ***positive pressure movement***. The excess air pushes out through cracks in the cabin walls and gaps in the doors, preventing the entry of contaminates.

Measuring devices are available to monitor air movement through a spray booth. One such device, called a manometer, is shown in **Figure 24-30**. Air movement is measured in cubic feet per minute, or CFM, and can be adjusted by varying the speed(s) of the fan(s). This is usually accomplished by changing the size of the fan pulleys.

As shop air is drawn into the spray booth, fresh replacement air is drawn into the shop from outside through a roof vent. In a colder climate, as heated shop air is replaced by cold outside air, the entire shop will rapidly cool. The solution is a device engineered to replace the heated air lost through exhaust called an ***air makeup unit***. When the outside temperature falls below 70°F (21.1°C), a furnace located in the makeup unit warms the air. The air is filtered before it enters the furnace and again before it enters the spray booth. **Figure 24-31** shows an air makeup unit.

The air makeup unit may also be capable of producing air as hot as 200° F. Exposing new paint to high temperature is called ***baking*** and is done to reduce drying time.

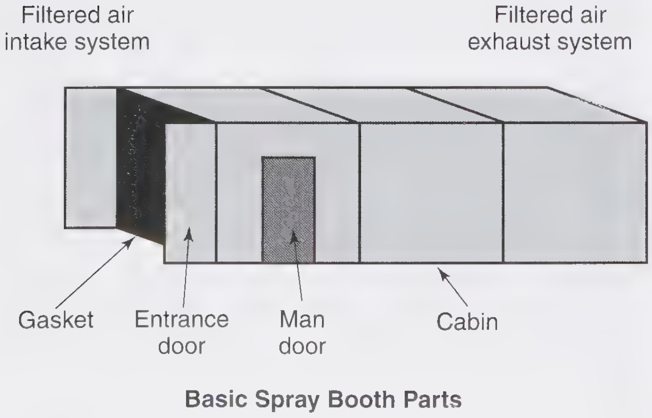


Figure 24-29. *The basic parts of a spray booth are the loading door, man door, cabin, filtered air intake system, and filtered air exhaust system.*

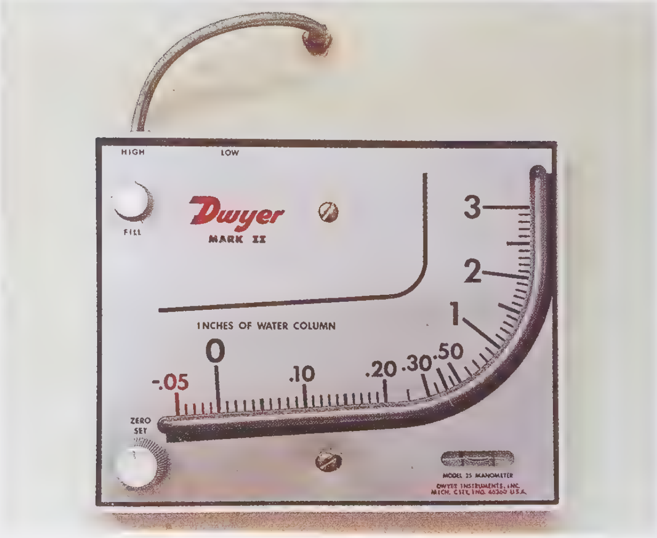


Figure 24-30. *The manometer measures the amount of air moving through the spray booth.*

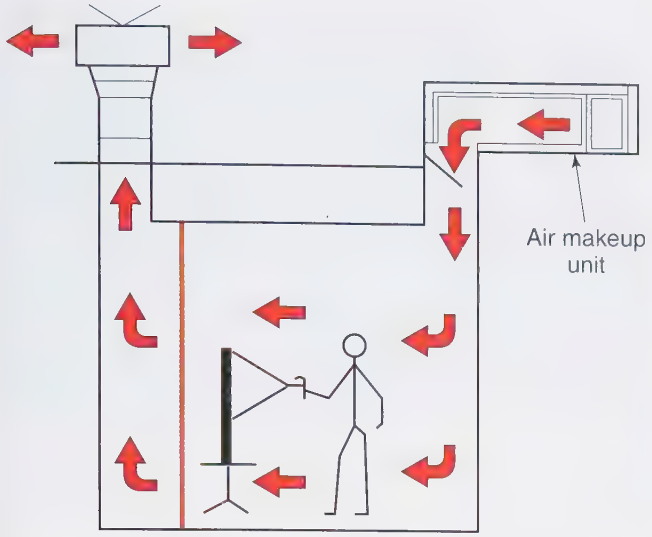


Figure 24-31. *An air makeup unit filters the air going into the spray booth. If the intake air is cold or cool, the air makeup unit can heat the air.*

After spraying is completed, solvent-laden air is purged from the booth and the bake cycle is initiated. The purge cycle lasts from 1–3 minutes, depending on the paint manufacturer's recommendations.

During the bake cycle, the air temperature inside the booth is raised to 140°–200°F (60°–93.3°C). The exhaust fan discharges less air during the bake cycle to minimize heat loss and fuel cost. However, enough air still must be discharged during the bake cycle to vent the solvents that are evaporating from the curing paint.

Baking booths are wired to turn lights off during baking, and back on when baking is complete.

WARNING

Stay out of the spray booth during the bake cycle. The high temperatures in the booth can cause burns and other physical harm.

Booths are available in both side-load and drive-through configurations. In confined spaces, a ***side-load spray booth***, **Figure 24-32**, can ease loading. In a side-load booth, the vehicle is placed on a track and pushed sideways into the cabin. A ***drive-through spray booth*** has a door at each end. The vehicle enters through one end of the booth and exits through the other.

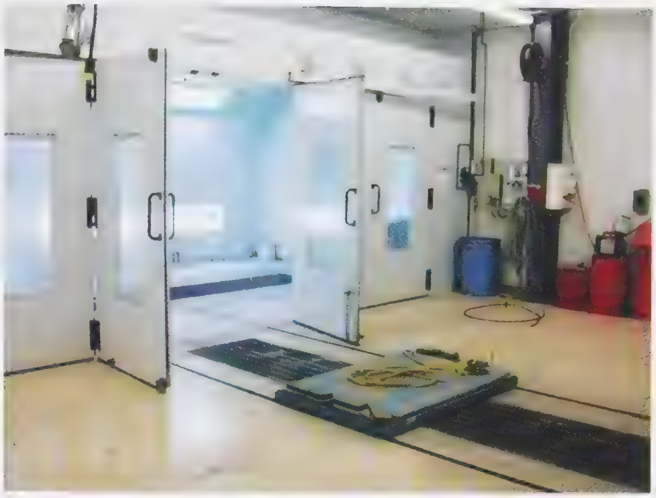


Figure 24-32. *A vehicle is placed on the ramp and pushed along tracks into a side-load spray booth.*

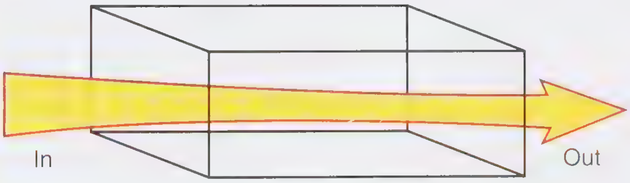
Spray Booth Types

Spray booth type is determined by the path air takes as it flows through the booth. The three types of spray booths used in the typical collision repair shop are the cross-draft booth, the semi-downdraft booth, and the downdraft booth. Each of these configurations will be discussed in the following sections.

Cross-Draft Booth

In a ***cross-draft spray booth***, air moves in through one end of the booth and flows out through the other end. See **Figure 24-33**. If the booth does not have an intake fan, the air enters through filters in the entrance door. If the booth has an intake fan, the air enters through filters at the end of the booth opposite the entrance door. In either case, the air moves from one end of the booth to the other, crossing over and around the vehicle.

The cross-draft air path exposes the vehicle to any contaminants present in the air. At the intake end of the booth, contaminants are blown into the wet paint. For this reason, cross-draft booths are considered inferior to downdraft spray booths. Nevertheless, cross-draft booths are still manufactured and sold. The primary advantage to a cross-draft booth is its low cost.



Cross-Draft Airflow

Figure 24-33. *The air moves over and across the vehicle in a cross-draft spray booth.*

Semi-Downdraft Booth

The air path of a ***semi-downdraft spray booth*** is shown in **Figure 24-34**. The air travels in through the roof at one end of the booth and out the other end. This path causes air to move over and across the vehicle. A semi-downdraft booth causes the same problems with contamination that a cross-draft booth does. The air moving across the vehicle picks up contamination and deposits it in the wet paint. A semi-downdraft booth also costs less than a downdraft booth.

Downdraft Booth

In a downdraft spray booth, the air enters through the roof and is exhausted at or near the floor. See **Figure 24-35**. Air does not flow across the vehicle, dramatically reducing the chance of contamination.

There are two types of downdraft spray booths, the side downdraft booth and the full downdraft booth. A ***side downdraft spray booth***, shown in **Figure 24-36**, draws air through filters on the roof and out through filters on the side walls.

In a ***full downdraft spray booth***, air enters through filters on the roof and exits through the floor. There are two types of full downdraft spray booths, the basement full downdraft spray booth and the pit full downdraft spray booth. A ***basement full downdraft spray booth*** is shown in **Figure 24-37**. The floor in this type of booth is covered with grating. There are two channels in the floor, one on each side of the vehicle. Exhaust air flows through these channels.

In a ***pit full downdraft spray booth***, **Figure 24-38**, exhaust air is drawn underneath the vehicle into a pit. In this design, the high speed of the exhaust air removes mist so effectively that no overspray is visible. Downdraft spray booths provide for the cleanest paint jobs.

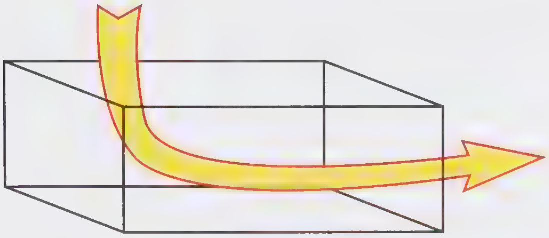


Figure 24-34. *The air enters through the ceiling on one end and exits at the other end in a semi-downdraft spray booth.*

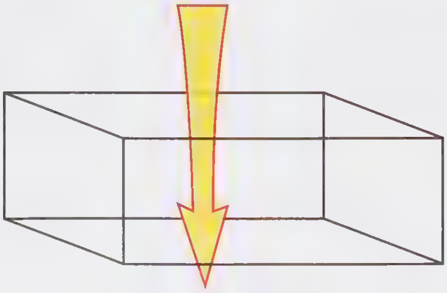


Figure 24-35. *Air enters through the ceiling and exits near the floor in a downdraft spray booth.*

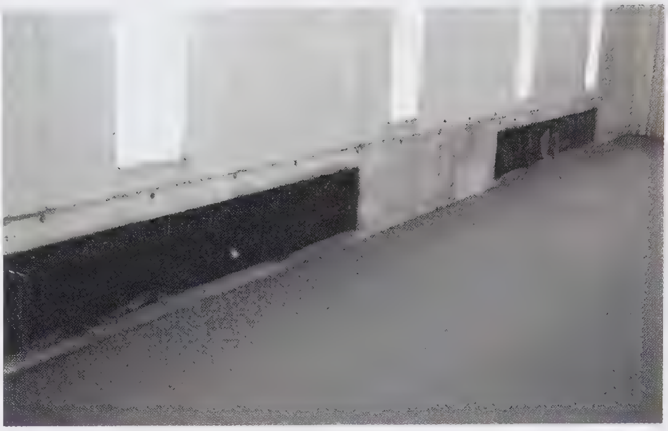


Figure 24-36. *Air exits through vents located in the side walls of a side downdraft spray booth.*

Spray Booth Maintenance

Whatever spray booth style is used, the exhaust filter will trap dried paint particles. As particles accumulate, or load up, in the filters, this debris begins to restrict airflow. Exhaust filters will load up much faster than the intake filters.

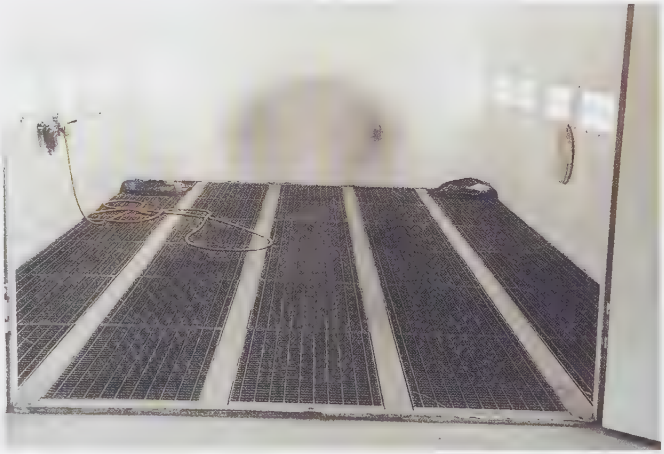


Figure 24-37. *Air is drawn through grates on the floor of a basement full downdraft spray booth.*

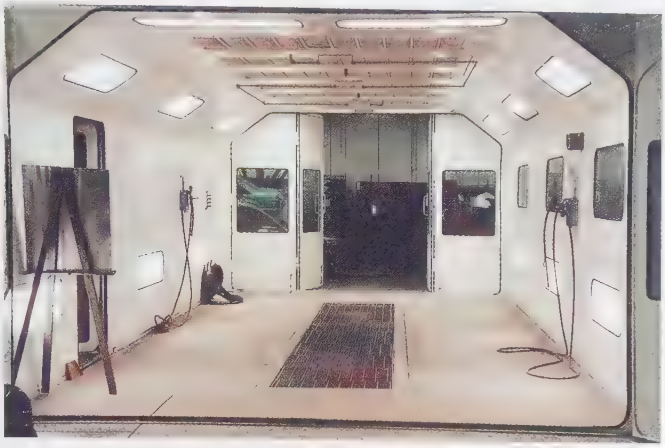


Figure 24-38. *The vehicle straddles the exhaust filter in a pit full downdraft spray booth.*

The interval for changing the filters depends on how often the booth is used. In most cases, filters must be replaced periodically. Some exhaust filters are designed to be cleaned in thinner and reused. Used disposable exhaust filters are considered ***hazardous waste*** because they are contaminated with paint particles. Hazardous waste must be disposed of properly. When the filters are changed, the grates or wire framework holding them in place should be pressure-washed.

NOTE

A manometer will give you an indication of when the filters need to be changed. Loaded exhaust filters will cause the air pressure inside the booth to increase.

In addition to changing filters, you must keep the booth clean. A clean spray booth will produce clean paint jobs.

Overspray will end up on the floor and walls after spraying. At a minimum, the booth should be blown out before each paint job. Run the exhaust fan while blowing out the booth. The exhaust fan filters will capture any dust that is blown toward them. Aim a blowgun at all cracks in the cabin walls and doors and the entire floor.

Periodically, the booth should be vacuumed out. If the spray booth has a floor drain, a pressure washer can be used to clean the cabin walls, doors, and floor. One problem with using water to wash down the booth is that the water may puddle and cause the cabin walls to rust.

Overspray on windows can be scrapped off with a razor blade. Overspray on the cabin walls can be removed with lacquer thinner or sanded with 1500-grit sandpaper. After sanding off the overspray, the cabin walls can be buffed.

Air leaks are caused by holes in the cabin or bad seals around the doors. Holes in the cabin can be filled with caulk. The seals around the doors will wear out with use. These seals should be replaced as needed.

Prep Station

The ***prep station*** is an area where the vehicle is readied for repainting. Many prep stations can be used for spraying primer and surfacer. Check local fire codes to see if spraying in a prep station is allowed. Some prep stations are specifically designed to remove sanding dust from the vehicle. Therefore, spraying is not allowed.

There are a variety of prep station designs available. The simplest consists of an exhaust filter, exhaust fan, and related duct work. This type of system may even be portable. A more elaborate system is shown in **Figure 24-39**. This prep station has a heated air makeup unit, an intake fan and filters, and an exhaust fan and filters. Curtains surround this full downdraft prep station. It can be used when sanding, spraying primer and surfacer, and trimming replacement parts. A prep station designed for painting can be used for basecoat and clearcoat spraying. This added flexibility will increase productivity in the paint shop.

Paint Mixing Room

As the name implies, a ***paint mixing room*** is for mixing paint. The tints, mixing bank, scale, and paint formulas are kept in this room. The paint mixing room has power ventilation, as well as explosion-proof lighting. The walls are made of the same material as a spray booth. In fact, most mixing rooms are adjacent to the spray booth.

Drying Equipment

Body shops are always looking for ways to increase productivity and reduce cycle times. Productivity is measured by the number of vehicles or paid labor hours that an individual or shop can complete per unit of time.

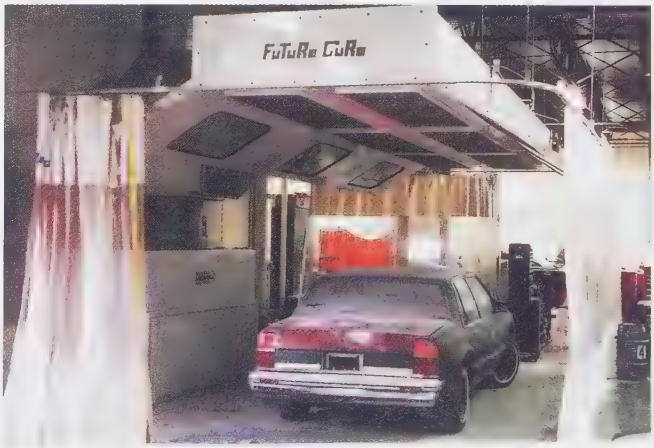


Figure 24-39. *This prep station features curtains to contain overspray and a pit below to remove it.*

Cycle time is the total number of hours required to complete a repair job, from the time the vehicle enters the shop until it is delivered to the customer. This cycle time includes not only the labor hours but also the amount of time required for the paint to dry and the wait time while the vehicle is not worked on. Any equipment that will speed the repair by shortening drying time will boost productivity. Drying equipment reduces cycle time and increases productivity by shortening drying, or cure, time. The three methods of drying used in the paint shop include baking, infrared curing, and UV curing. Each method will be detailed in the following sections.

Baking

Some spray booths are equipped with a high-temperature air makeup unit. This unit allows the paint to be baked on. Baking paint reduces overall repair time. The paint manufacturer provides recommended baking temperatures and times. A typical paint baking procedure is as follows:

1. Purge the booth of spray mist for 3 minutes after spraying is completed.
2. Rapidly increase booth temperature to 200°F (93.3°C) for five minutes.
3. Reduce the temperature to 180°F (82.2°C) and then bake the vehicle at this temperature for 20 minutes.
4. Remove the vehicle and allow it to cool.

During the baking cycle, the spray booth's intake and exhaust fans run at a slower speed. This allows the solvents evaporating from the paint to be removed. Some of the exhaust air is recycled to preserve heat.

In a high-production shop, the spray booth may consist of two compartments—one for spraying and one for drying. The vehicle is painted in the spraying compartment, and when done, it is moved into the drying compartment. This allows another vehicle to be painted while the first vehicle dries.

Infrared Lamp Curing

Infrared lamps use heat to speed curing. An infrared lamp is shown in **Figure 24-40**. The infrared energy excites molecules in the paint, producing heat, which shortens cure time. The depth to which infrared energy penetrates the paint depends on the type of pigment. Short wave and medium wave infrared lamps are available. Depending on the paint pigment, short wave curing is slightly faster than medium wave curing.

The distance between the paint and the infrared lamp is critical. If the lamp is too close, the paint will blister. If the lamp is too far away, it will not produce enough heat to fully cure the paint. Some infrared lamps have sensors that detect distance. The lamp may also have a timer. The paint manufacturer will generally recommend the amount of time necessary for a full cure. Position the infrared lamp at the proper distance and set the timer.

UV Curing

UV dryers do not use or produce heat. Instead, they produce UV (ultraviolet) radiation. Special UV-cure paint is formulated to react and cure when exposed to UV radiation. UV-curable paint—undercoats and clearcoats—cure in two minutes or less. UV radiation is divided into three ranges: UVA, UVB, and UVC. Exposure to the UVB and UVC can cause cancer. Dryers that produce UVB and UVC are too dangerous to be used in a body shop environment, where workers are not isolated from the radiation.

The UV dryers shown in **Figure 24-41** produce UVA radiation similar to that produced by a tanning machine.

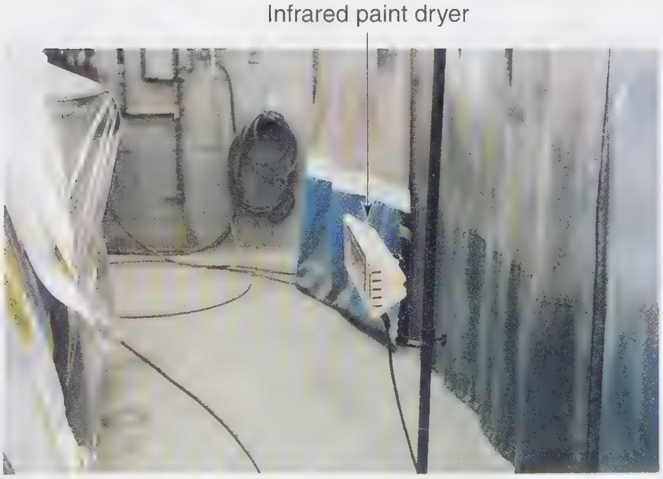


Figure 24-40. *Infrared paint dryers heat the surface of the vehicle to speed the rate of cure.*

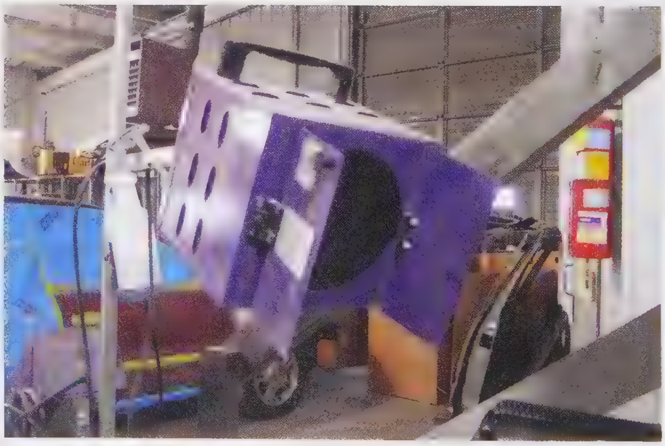


Figure 24-41. *UV paint is cured with a UVA dryer. The UVA dryer produces UV radiation.*

The UVA radiation can cause sunburn. Do not look directly at the UV dryer bulbs in operation without wearing protective UV-rated glasses. Some sunglasses, although tinted, may not be UV rated.

UVA radiation moves in a straight line from the dryer to the vehicle. The radiation does not cause a reaction in areas that are not directly in line with the dryer. A side-mirror or some other protruding part may cast a shadow on a panel and prevent the shaded area from being cured.

The UV dryer should be large enough to cure an entire panel or easily portable so that it can be moved as required. Hand-held units are available.

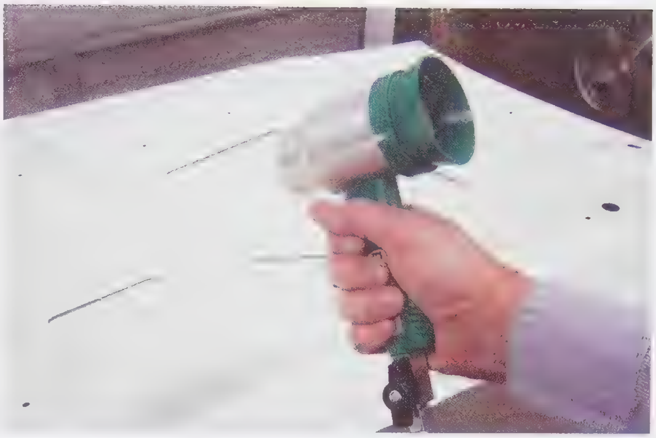


Figure 24-42. *A hand-held air gun is used to dry waterborne paint.*

Air Drying

Air movement, especially turbulent air movement, is what dries waterborne paints. Overhead fans or side wall air jets can supplement air movement in a downdraft spray booth to increase the drying rate of waterborne finishes. An air gun is a hand-held device designed to move a large volume of filtered air, **Figure 24-42**. Multiple air guns can be mounted on a stand to provide enough air volume to dry the entire side of a vehicle

Spray Gun Cleaner

To prevent the needless discharge of VOCs into the atmosphere, paint shops will use a spray gun cleaner. A ***spray gun cleaner*** is an enclosed unit that pumps thinner through the paint passages of a spray gun. **Figure 24-43** shows one type of spray gun cleaner. This cleaner has a thinner reservoir in the bottom and an air-powered pump. The pump draws thinner out of the reservoir, filters it, and forces it through a system of tubes and nozzles. The nozzles spray the thinner in the enclosure. Spray guns and cups are placed on the nozzles and the spray gun trigger is blocked open. Some units are equipped with timers. Two minutes should be enough time to clean a spray gun.

Every time a spray gun is cleaned, the thinner becomes more contaminated. A spray gun cannot be cleaned with contaminated thinner. Therefore, the spray gun cleaner should be periodically drained, rinsed, and filled with clean thinner. The frequency of this service depends on how often the spray gun cleaner is used. In a busy shop, the cleaner may be drained as often as once a week.

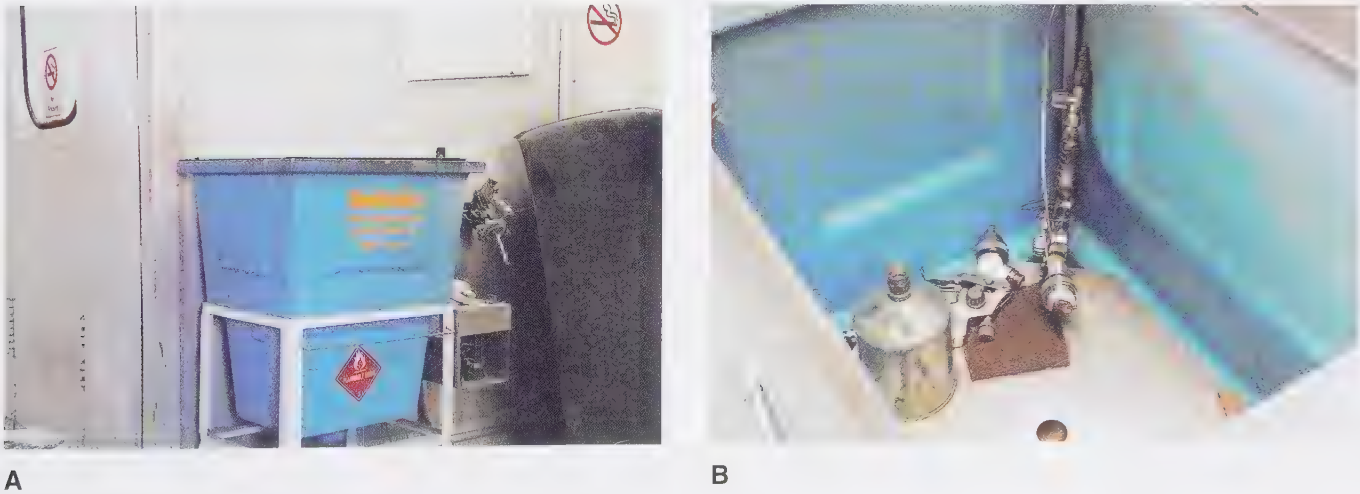


Figure 24-43. *A—Outside view of a spray gun cleaner. B—The spray gun is placed on nozzles inside the spray gun cleaner.*

Vacuum System

Dry sanding creates lots of dust. This dust will flow throughout the shop and cover every horizontal surface. A ***vacuum system*** will help keep the shop clean. A vacuum system consists of a central vacuum unit, hoses, and special air tools. The tools feature internal ports designed to convey dust through the pad and into a canister. See **Figure 24-44**. The sandpaper has holes that align with the ports in the tool's pad. The central vacuum unit is powered by electricity, while the shop's compressed air system powers the tool.

Solvent Recycler

A great deal of waste solvent is generated by a busy body shop. This waste solvent is primarily made up of thinner from the spray gun cleaner and is considered hazardous waste. A body shop must pay a licensed waste hauler to properly dispose of this material, so any technology that can reduce the amount of hazardous waste is welcome. A ***solvent recycler*** is designed to do just that by removing the contaminants from the used solvent.

The recycler heats the waste solvent, causing the thinner to evaporate and leave the contaminants behind. The contaminants are then removed, and the vaporized thinner is cooled and condensed back into a liquid that can be used again. The contaminants, a solid mass, can then be disposed of as solid waste.

Compressed Air System

Good paint jobs require a reliable source of clean, dry compressed air. This air is supplied by the shop's compressed air system, which consists of an air compressor, air dryer, air piping, air regulators, and air hoses.

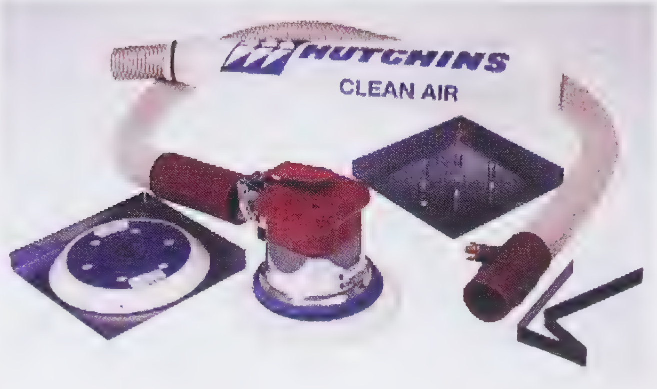


Figure 24-44. *The vacuum system pulls the sanding dust through the sanding pad while sanding.*

Air Compressor

The air compressor is the heart of the paint shop. An ***air compressor*** takes in air at atmospheric pressure (14.7 psi) and raises it to pressures as high as 175 psi. The pressure increases because the atoms in the air are forced closer together by decreasing the volume, or space, they occupy. See **Figure 24-45**.

It is important to understand the inverse relationship between volume and pressure. In a sealed system, air pressure increases as volume decreases. Conversely, air pressure decreases as volume increases.

Air compressors are rated by the volume of air they can supply per minute. This volume is measured in cubic feet per minute, or CFM, at a given pressure. The pressure is measured in pounds per square inch, or psi. To operate properly, air tools must be supplied with a certain volume of air at a specific pressure. Spray guns are especially sensitive to air pressure and volume.

There are two types of air compressors commonly used by body shops: ***piston air compressors*** and ***rotary screw air compressors***. A piston air compressor design is similar to an internal combustion engine. The movement of pistons within cylinders is conveyed to a crankshaft by connecting rods. Air is let in and out of the cylinders by valves. No ignition takes place inside the cylinders. The power to turn the crankshaft and to make the pistons compress air is provided by an external, usually electric, motor. **Figure 24-46** shows a cutaway of a piston air compressor.

Piston air compressors may be either single-stage or two-stage units. See **Figure 24-47**. In a ***single-stage piston air compressor***, **Figure 24-47A**, air is drawn into a cylinder and a piston compresses the air in one stroke.

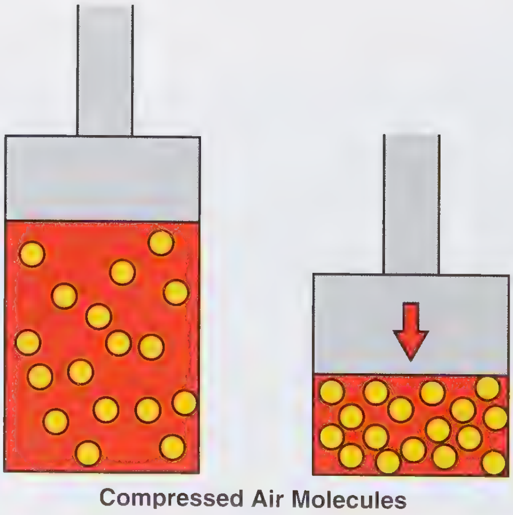


Figure 24-45. *An air compressor rams air molecules together, raising the air pressure.*

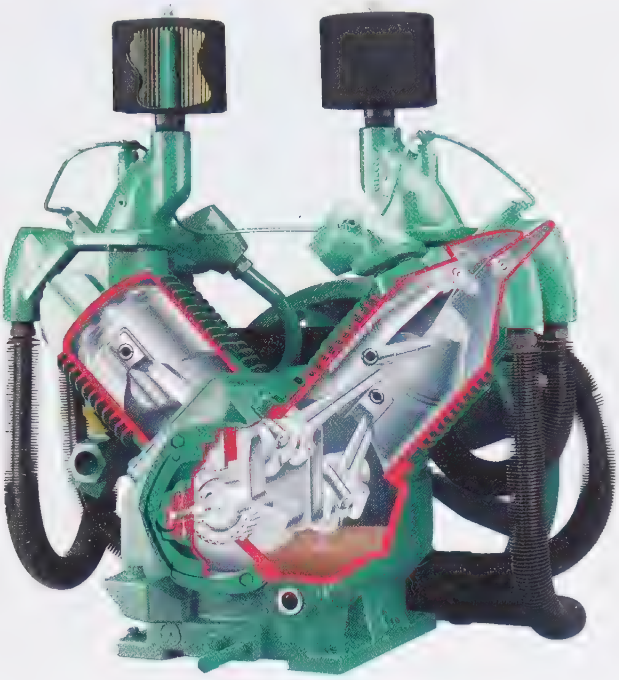


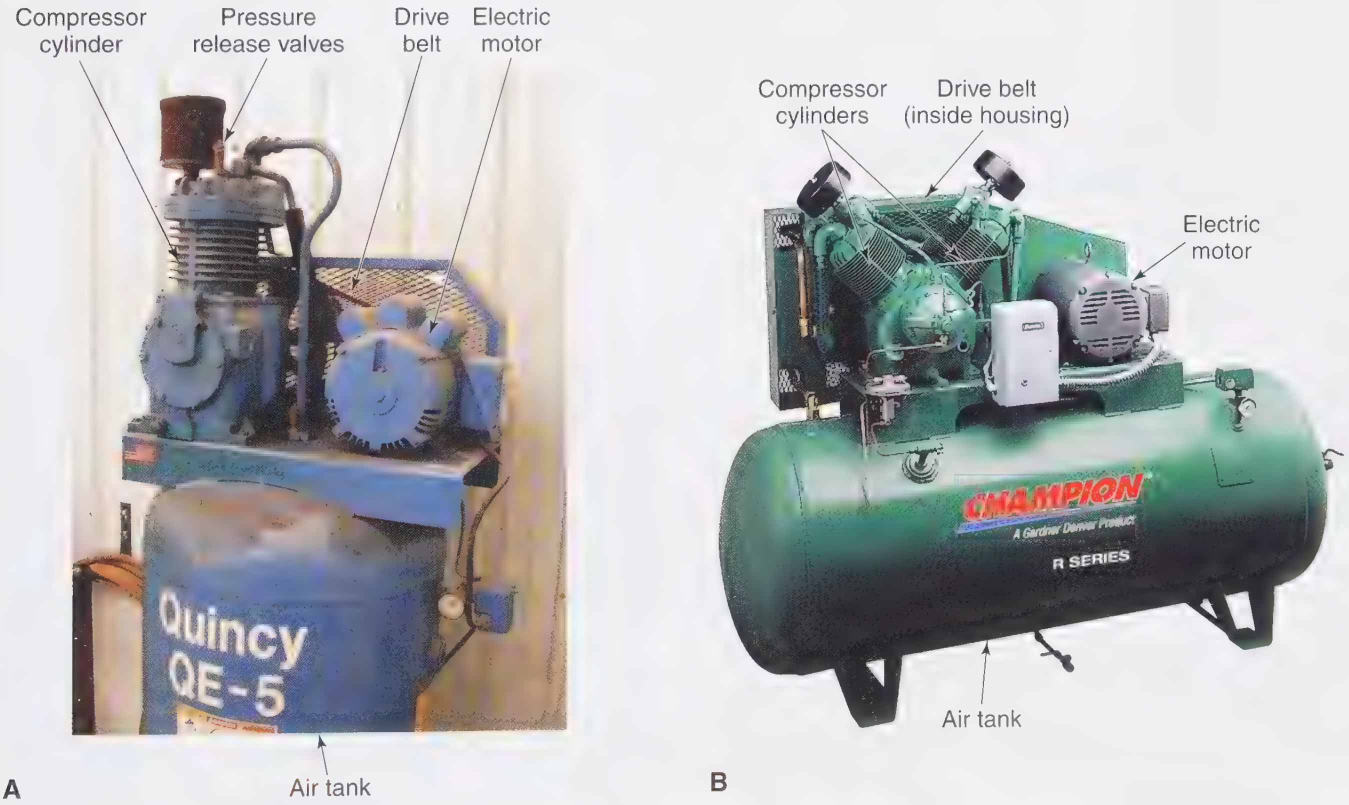
Figure 24-46. *This cutaway drawing shows the pistons, cylinders, connecting rods, and crankshaft of a piston compressor. (Gardner-Denver)*

The compression that takes place in the cylinder produces the ***discharge air pressure***. The maximum air pressure is about 100–125 psi for a single-stage piston air compressor. To produce a greater volume of air, some single-stage piston air compressors have more than one cylinder.

A ***two-stage piston air compressor***, **Figure 24-47B**, can produce higher pressures more efficiently than a single-stage piston air compressor. A two-stage piston air compressor compresses the same air twice in two different cylinders. The air is first compressed to about 100 psi in a relatively large cylinder. The compressed air then passes through an intercooler to a smaller cylinder. In the smaller cylinder, a piston compresses the air to the discharge air pressure—175 psi or greater. The intercooler lowers the temperature of the air that was compressed in the first stage. Cooler intake air in the second stage allows more efficient operation.

After the air is compressed, it is discharged into a storage tank. This storage tank can be vertical or horizontal, as shown in **Figure 24-47**. The volume of the tank can range from as little as 60 gallons to more than 140 gallons.

A compressor is generally powered by an electric motor, although gas-powered models are available. Motors are rated by horsepower. In a body shop, the compressor motor should be a minimum of 5 HP. Greater demand for shop air requires bigger motors and larger air compressors.



Compressor cylinder
Pressure release valves
Drive belt
Electric motor
Air tank
A
Compressor cylinders
Drive belt (inside housing)
Electric motor
Air tank
B
Quincy QE-5
CHAMPION
A Gardner Denver Product
R SERIES

Figure 24-47. *A—This single-stage compressor has a vertical tank. B—This two-stage air compressor consists of horizontal tank, electric motor, and two compressing cylinders. (Gardner-Denver)*

The individual components of an air compressor are rated by the amount of pressure they can handle. If an air pressure greater than the rated capacity is created, a component, such as the pipe that connects the compressor to the tank, may rupture and fail. To prevent this, ***pressure relief valves*** are installed on the air compressor components. These valves are set to release air from the compressor, reducing system pressure when an excessive air pressure level is reached.

A pressure relief valve can be checked for proper operation by pulling on the valve's ring when the compressor is in operation. If the valve is working properly, it will release compressed air when the ring is pulled. See **Figure 24-48**.

A piston-type air compressor is operated by an on-off switch. When the pressure in the storage tank has reached the desired cut-out pressure, for example, 175 psi, the switch automatically turns off the motor. As air is drawn out of the storage tank by air tool usage, the air pressure in the tank will drop. When the air pressure drops below a predetermined level, the switch turns on the air compressor motor. The motor runs, compressing air until the desired cut-out pressure is reached. If the air usage is heavy, the air compressor may not be able to reach the cut-out air pressure, so it may operate continuously. A properly sized air compressor will not operate continuously, but will cycle on and off as needed. A 60% duty cycle is desirable. This means that the compressor operates for 60% of the time and is shut off for 40% of the time. An air-cooled, piston-type air compressor reaches a temperature of 300°–400°F (148°–204°C) during operation. The shut-off time allows the air compressor to cool down.

A rotary screw air compressor contains two rotors designed to mesh, causing the air trapped between them to be compressed. See **Figure 24-49**. The rotors utilize oil to create an air-tight seal. The oil is filtered out of the discharge air. Rotary screw air compressors have a 100% duty cycle and operate at lower temperatures 120°–200°F (48°–93.3°C) than piston air compressors.

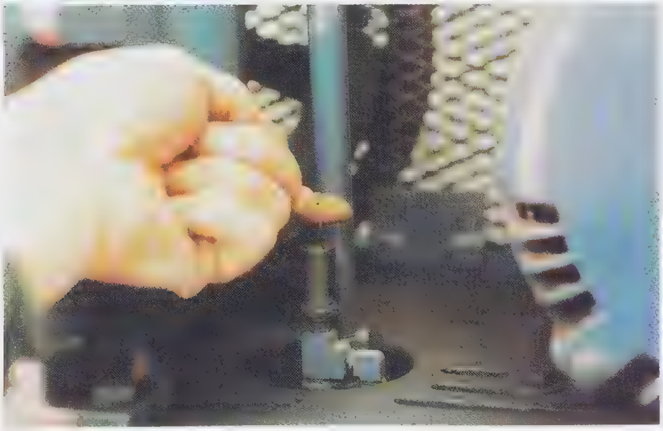


Figure 24-48. *Check the operation of a pressure relief valve by pulling the ring.*

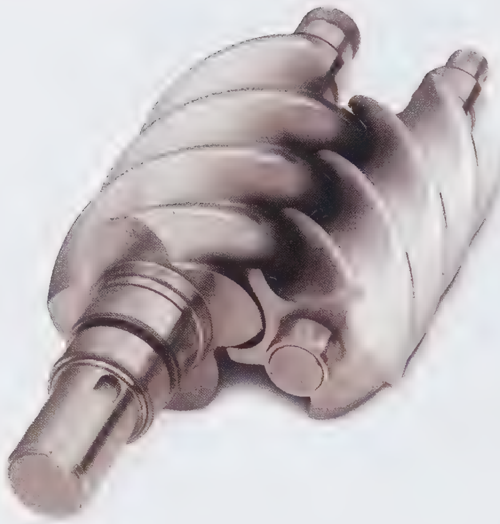


Figure 24-49. *In a rotary screw compressor, an electric motor spins the rotors to trap and compress air. (Gardner-Denver)*

Air compressor maintenance demands periodic oil and air inlet filter changes. Drive belts should be checked for wear and kept tight. Water is an undesirable by-product of compressing air and warm air holds more water. To keep water out of the shop's air lines, the compressor's storage tank should be drained of water on a daily basis by opening the drain valve, **Figure 24-50**. A dirty compressor will run hotter, so keep the pump and motor clean. Air cooled compressors should be located in well-ventilated areas. Outside air, which is cleaner than shop air, should be ducted to the compressor air intake.

The amount of air consumption, measured in CFM, is used to determine the size of the air compressor needed for a shop. **Figure 24-51** shows the air consumption

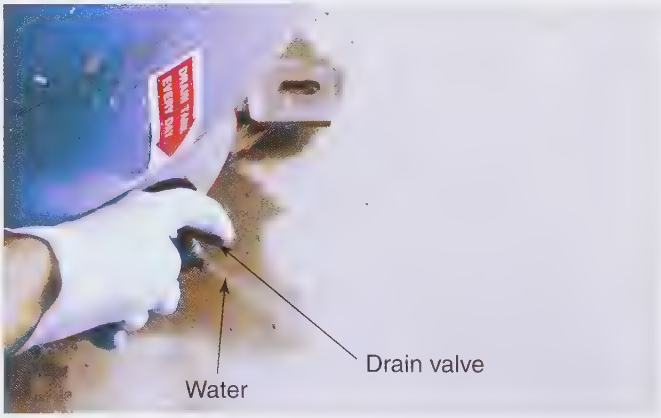


Figure 24-50. *Water is a by-product of compressing air and accumulates at the bottom of the tank. Drain the water every day.*

Air Pressure Range CFM	Equipment	Average Free Air Consumption CFM‡
70–100	*Air Filter Cleaner	3.0
70–100	*Body Polisher	2.0
70–100	*Body Sander (Orbital)	5.0
70–100	Brake Tester	3.5
70–100	*Carbon Remover	3.0
70–100	*Car Washer	8.5
90–100	Dusting Gun (Blowgun)	2.5
120–150	*Grease Gun	3.0
70–100	*Panel Cutter	4.0
70–90	*Drill, 1/16″ to 3/4″	4.0
125–150	*Impact Wrench, 3/8″ sq. dr.	2.0
125–150	*Impact Wrench, 1/2″ sq. dr.	3.5
125–150	*Impact Wrench, 5/8″ sq. dr.	5.0
125–150	*Impact Wrench, 3/4″ sq. dr.	7.5
125–150	*Impact Wrench, 1″ sq. dr.	10.0
70–90	*Die Grinder	5.0
90–100	*Vertical Disc Sanders	10.0
90–100	*Filing & Sawing Machine, small	3.0
90–100	*Filing & Sawing Machine, large	5.0
90–100	*Burring Tool	5.0
145–175	†Hydraulic lift	6.0
125–150	Hydraulic Floor Jacks	6.0
120–150	Pneumatic Garage Door	3.0
90–100	Radiator Tester	1.0
90–100	Spark Plug Cleaner	5.0
90–100	Spark Plug Tester	.5
90–100	*Air Hammer	4.0
90–100	*Tire Hammer	12.0
125–150	*Bead Breaker	12.0
90–100	*Engine Cleaner	5.0
90–100	*Paint Spray Gun (Production)	8.5
90–100	*Paint Spray Gun (Touch-Up)	3.5
90–100	*Paint Spray Gun (Undercoating)	19.0
90–100	Spring Oiler	4.0
125–150	Rim Stripper	6.0
125–150	Tire Changer	1.0
125–150	Tire Inflation Line	1.5
125–150	Tire Spreader	1.0
125–150	*Vacuum Cleaner	6.5

*These devices are to be considered as continuously operating devices when operating normally. All other devices listed are to be considered as intermittently operated when operating normally. When the devices consist of a large number of the continuously operating type, and if only a few are to be used at one time, the compressor should have a capacity at least equal to the total consumption of all those tools used simultaneously, in addition to the consumption of all the intermittently operated tools, if any.
†Note: This is for 8,000 lbs capacity. Add .65 CFM for each 1,000 lbs capacity.
‡Always check with tool manufacturers for actual consumption of tools being used. The above is based on averages and should not be considered accurate for any particular make of tool.

Figure 24-51. *Analyzing this chart and adding the air consumption of various tools will give an estimate of how much compressed air is required by a shop.*

ratings of typical air tools. The air compressor should have the capacity to provide enough air volume to power all the tools that will be in use at any given time. Most body shop air tools are not in continuous use, so you cannot add up the CFM consumption ratings of every tool in the shop to determine the air compressor needed. Instead, you must take the time necessary to realistically estimate tool use and size the compressor accordingly. If inadequate air volume is present, increasing cut-out air pressure will not compensate. The inverse relationship between air pressure and air volume means that increasing air pressure will cause more leaks in the air system and will not provide additional volume.

Air Piping and Hose

Compressed air leaves the air storage tank and moves to the work area through rigid piping that is typically mounted along the walls of the shop. Flexible air hose then transports the compressed air from the piping to the air tool. As mentioned previously, air tools need a specific air pressure and volume to operate properly. Therefore, the inside diameter of the air piping and hose is an important consideration. Larger piping and hose sizes (3/4"–1") will minimize the air pressure drop from the compressor to the air tool. Air pressure drop is a reduction in air pressure caused by friction created as air atoms move along the inside of the pipe or hose. The friction reduces the energy of the atoms, lowering pressure. In smaller diameter pipes and hoses, there is more friction than in larger diameter pipes and hoses. **Figure 24-52** shows the air pressure drop in various diameters of hoses. The amount of air pressure drop in a pipe or hose is also dependent on the length and diameter of the pipe or hose. The longer the pipe or hose, the greater the friction and the greater the pressure drop. Some recommendations on air piping include the following:

- Piping should be made of galvanized steel, black iron, or copper.
- The piping should be looped as shown in **Figure 24-53**. Notice how this compressed air system is designed. The main air piping forms a rectangular loop. Looping equalizes the pressure in the air system. Smaller diameter piping, called drops, takes air to several workstations and the spray booth.
- To minimize vibration in the piping, a flexible connector should be installed between the air compressor and the piping. See **Figure 24-54**.
- Drops to a regulator should be set up so that the “T” is positioned at the top of the pipe, not the bottom. See **Figure 24-55**.
- The piping should be well supported to minimize vibration. Vibration causes leaks.
- Pipes containing rust or scale will decrease pressure and volume.

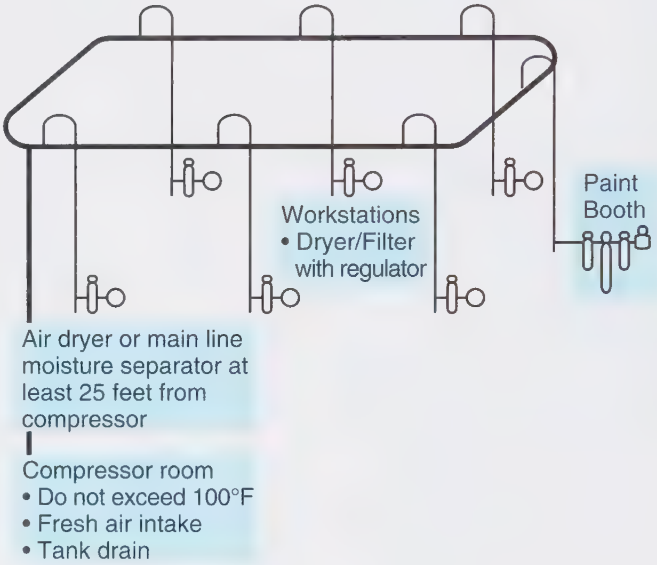

Workstations
• Dryer/Filter with regulator
Paint Booth
Air dryer or main line moisture separator at least 25 feet from compressor
Compressor room
• Do not exceed 100°F
• Fresh air intake
• Tank drain

Figure 24-53. *Looping the pipe will equalize the air pressure in the system.*

Air Hose Pressure Drop

Air hose inside diameter (ID) and length	At 15 CFM airflow	At 18 CFM airflow	AT 20 CFM airflow	At 25 CFM airflow
1/4″ ID x 20 ft.	-20 psi	-26 psi	-28 psi	-34 psi
5/16″ ID x 20 ft.	-7 psi	-10 psi	-12 psi	-20 psi
3/8″ ID x 20 ft.	-2.8 psi	-4 psi	-4.8 psi	-7 psi

Figure 24-52. *Friction in the pipe and hose causes air pressure to drop. The pressure drops shown here are for a 20' air hose.*

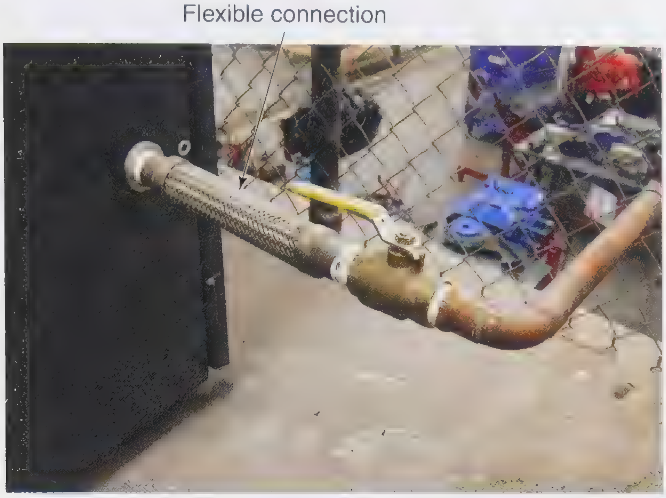


Figure 24-54. *This flexible connection isolates the compressor vibration from the piping system.*

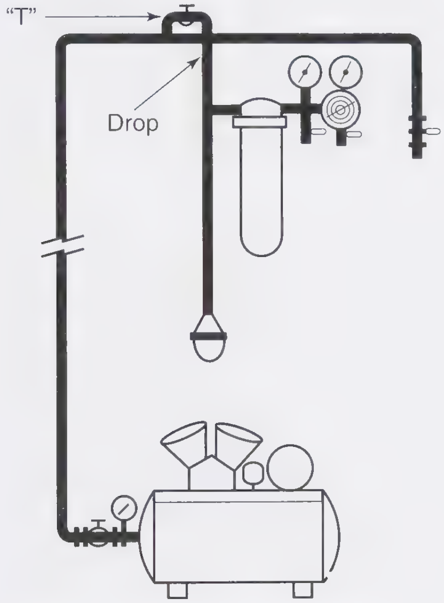


Figure 24-55. *Taking a drop from the top of the pipe will minimize the amount of debris and water in the drop.*

Dryers and Filters

To achieve a satisfactory paint job, clean air must be supplied to the spray gun. Compressed air contains moisture, oil, and other contaminants. All of these contaminants must be removed from the air to avoid painting problems.

Two types of dryers are used to remove moisture from compressed air: a refrigerator dryer and a desiccant dryer. Friction between air molecules creates heat when air is compressed. Warm air can hold more water vapor than cool air. When moisture-laden air cools to below the dew point, the water vapor in the air condenses to a liquid. A ***refrigerator dryer*** cools the compressed air below the shop temperature, causing moisture in the air to condense. The ***condensate*** (product of condensation) can then be drained from the compressor. A refrigerator dryer is shown in **Figure 24-56**.

A ***desiccant*** is a chemical that absorbs water vapor. In a ***desiccant dryer***, **Figure 24-57**, the compressed air passes over a desiccant, which draws out, traps, and contains the water vapors. The desiccant can hold only so much water, so once it's full, it must be changed. The desiccant may change color as it absorbs moisture. Usually, shops follow a schedule for replacement based on the manufacturer's recommendation.

Figure 24-56. *A refrigerator dryer cools the compressed air, allowing for more efficient moisture removal.*

DEVILBISS
CLEANAIR

Figure 24-57. *This canister contains a desiccant that draws moisture out of the air passing through it.*

Some compressed air systems have a refrigerator dryer near the air compressor and a desiccant dryer in the spray booth. The refrigerator dryer removes moisture from the air supplied to the entire shop. In the spray booth, where moisture in the lines could cause major problems with the paint, the desiccant dryer removes the small amount of remaining moisture in the air line.

Oil will seep past the rings on a piston compressor and may escape from a rotary screw compressor. This oil can cause serious problems in a paint spraying air system. An oil filter is shown in **Figure 24-58**. This device removes oil vapor from compressed air. The oil filter is installed on the air line in the spray booth.

As compressed air moves through the piping, particles, such as rust from the inside of black iron pipe, may be picked up and carried through the system. These particles can show up in the paint as specks of dirt. The particles can be removed with the filter shown in **Figure 24-59**. The filter is located inside the spray booth. Particle filters must be changed when they become clogged. A common filter sequence in a spray booth is particle filter, oil filter and desiccant dryer.

An inline air filter located at the spray gun will remove a small amount of moisture from the air entering the gun. This air filter is a good preventative measure, even on air systems equipped with a refrigerator dryer.

Air Regulator

The ***air regulator***, **Figure 24-60**, is used to set discharge air at the desired pressure. The regulator should be located at the end of the hard piping but before the flexible air hose. Another regulator is required in the spray booth to set spray gun air pressure.

The air pressure should be set to compensate for the expected pressure drop due to air hose length. For example in a 20' long 3/8" diameter hose at 25 CFM, the expected air pressure drop is 7 psi. Adjust the regulator to 7 psi more than is required. If a spray gun requires 35 psi, set the regulator at 42 psi. Regulators may not be necessary in the shop. Air tools, such as ratchets and sanders, have internal airflow adjusters. Actual air pressure is more important for a spray gun than an air tool.

Air Hose

The ***air hose*** is connected to the air regulator and delivers air to the spray gun or air tool. As with piping, air hose diameter is important. To minimize pressure drop and ensure that enough air volume is delivered, hose internal diameter should be at least 5/16". High-flow

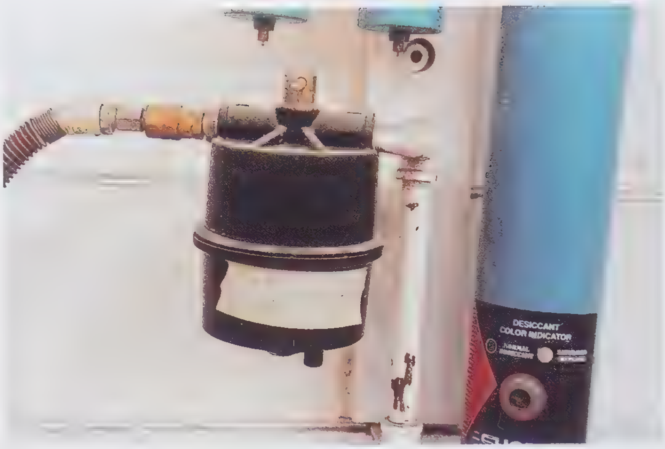


Figure 24-59. *This filter removes dirt and rust particles.*

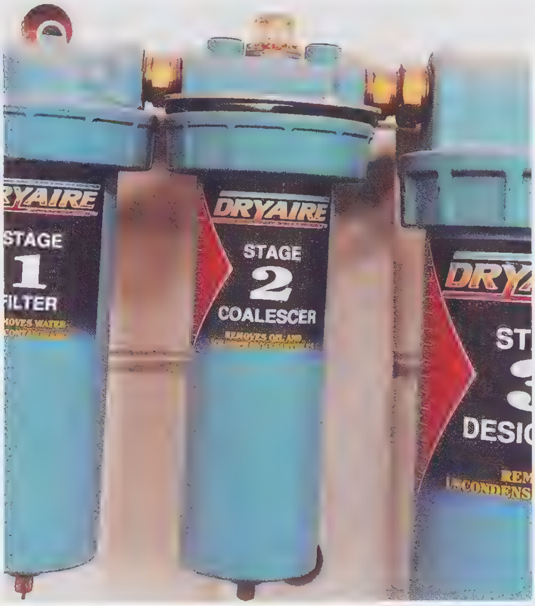


Figure 24-58. *Oil, which can ruin a paint job, is removed by this filter.*

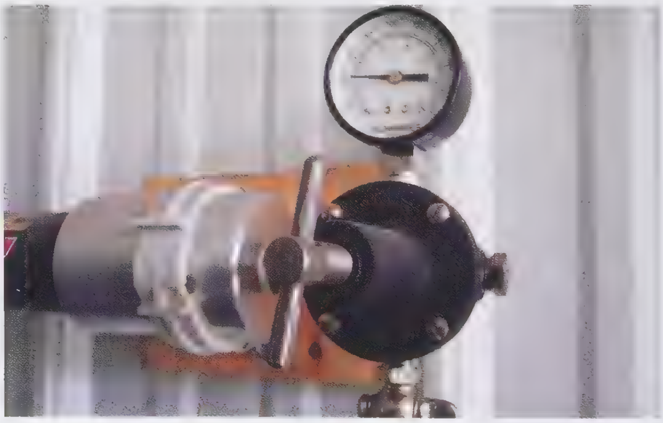


Figure 24-60. *The gauge on this air regulator indicates the discharge air pressure. Turning the knob on the regulator adjusts the discharge air pressure.*

fittings should always be used, as any restriction in the air hose will contribute to air pressure drop. A comparison of fittings is shown in **Figure 24-61**. High-flow fittings will allow a larger volume of air to pass through them than standard fittings. Long air hoses will cause a greater drop in air pressure than shorter hoses. In a spray booth, the hose should be no longer than 35'. In baking spray booths, the air hose used must be capable of withstanding the elevated baking temperature.

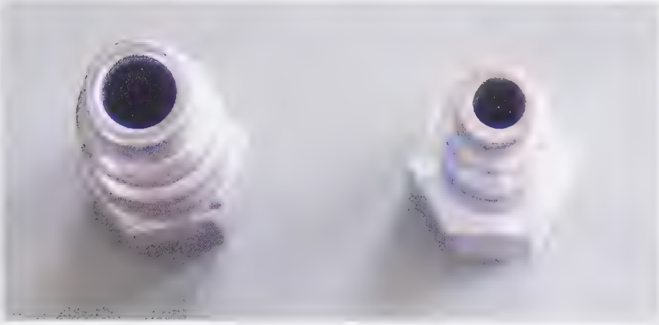


Figure 24-61. *Notice the difference in the diameters of these hose fittings. The larger fitting can move more air with less loss in air pressure.*

CAUTION

Do not drive over air hoses. Driving over air hoses will cause internal breakdown, ruin the hose, and may introduce bits of rubber debris into the paint.

Recycling Air System

The compressed air used to power air tools is discharged once the air does its work inside the tool. A ***recycling air system*** recovers the discharged air and sends it back to the air compressor. The recovered air, which has already been dried and filtered, is recompressed and used again. A recycling air system operates more efficiently than a conventional compressed air system because much of the air fed into the air compressor is clean and partially compressed. A recycling air system requires a special intake manifold on the air compressor as well as two hoses to each air tool. **Figures 24-62A and 24-62B** show the air compressor and the air tool. One hose takes compressed air to the tool; the other hose sends recovered air back to the air compressor.

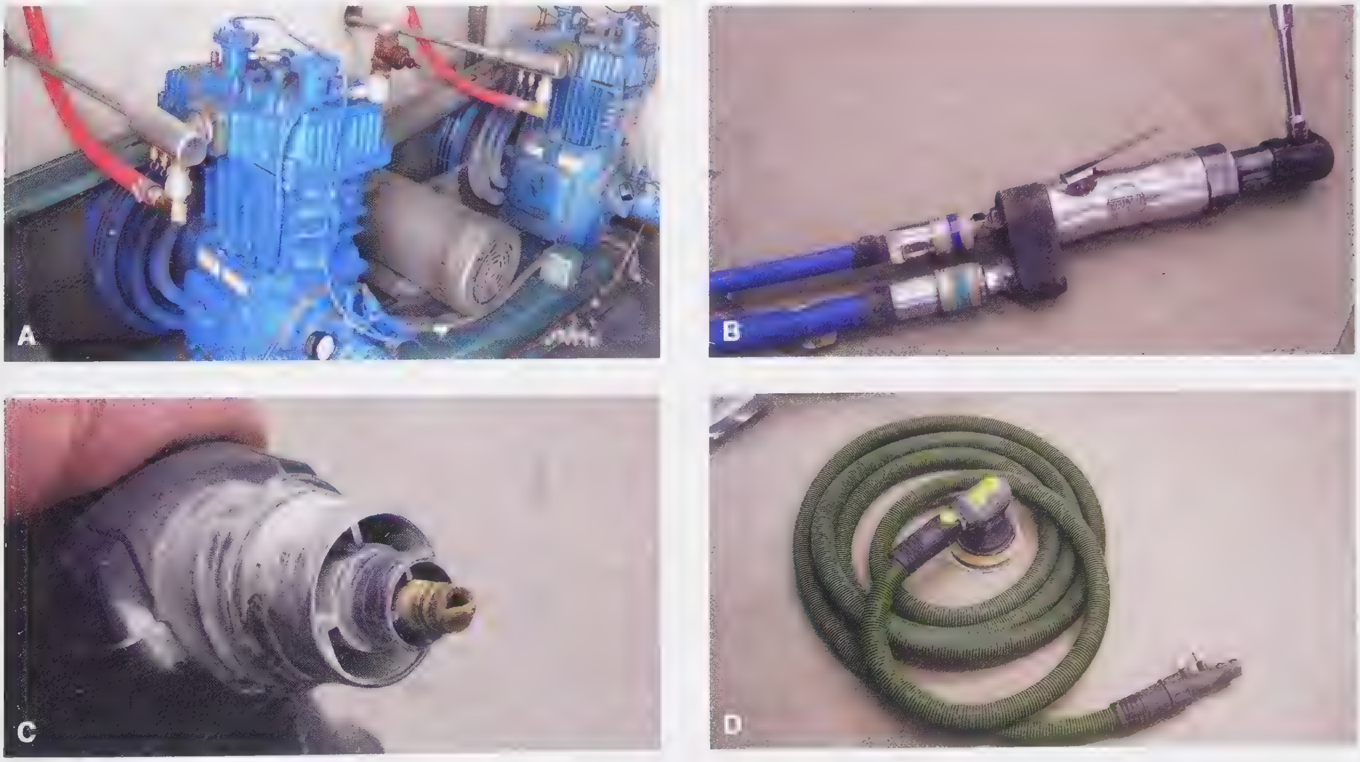


Figure 24-62. *A—A recycling air compressor has a special intake manifold. B—One air line brings compressed air to the tool; the other line conveys recovered air back to the compressor. C—This air tool has orifices for compressed air and recycled air (to power the tool and recycle the compressed air), as well as a vacuum duct for dust-laden air. A single hookup connects all three. D—The DA sander is hooked up to the hose. Note that the far end of the hose has connectors for compressed and recovered air.*

Spray guns cannot be operated off a recycling air system, but air tools such as ratchets, drills, and sanders can. A sander that uses a vacuum system, as shown in **Figures 24-62C** and **24-62D**, can also operate from a recycling air system. Air tools are much quieter when powered by a recycling air system. Air tools can be retrofitted for a two-hose hookup, but tools designed specifically for recycled air systems tend to have more power than those that have been retrofitted.

Additional Refinishing Equipment

Additional refinishing equipment includes equipment that is used to clean, strip, mask and paint a vehicle. A pressure washer can clean a vehicle before it enters the paint shop. Various types of blasters will remove the paint from a vehicle. Masking equipment dispenses masking paper and tape. A paint shaker speeds up paint mixing by combining settled paint components without requiring the refinish technician to stir them. A painting platform allows the painter to reach the roof or hood of an SUV, pickup truck, or van. A painting positioner holds parts that have been removed from a vehicle for painting. Powder coating equipment applies a durable finish without spraying. An infrared thermometer is used to check the surface temperature of curing paint.

Masking Equipment

Masking equipment is designed to quickly dispense masking materials, such as masking paper, masking tape, or masking plastic. A 3-roll masking machine is shown in **Figure 24-63**. This machine holds 3 different widths of masking paper. As the paper is pulled from the roll, masking tape is automatically applied to the edge of the paper. The masking paper and tape are cut to the desired length by a blade located just above the roll. There are many other styles of masking machines. Some types hold only one roll of paper. Another type of masking machine dispenses masking plastic. This machine is wide enough to hold a 3'-wide roll of plastic. Wheel maskers consist of canvas stretched over a nearly circular frame. The masker is placed over a wheel to protect it from overspray while painting. Over time, these maskers accumulate a large amount of dried paint and if not blown off carefully, can contribute to contamination in the spray booth.

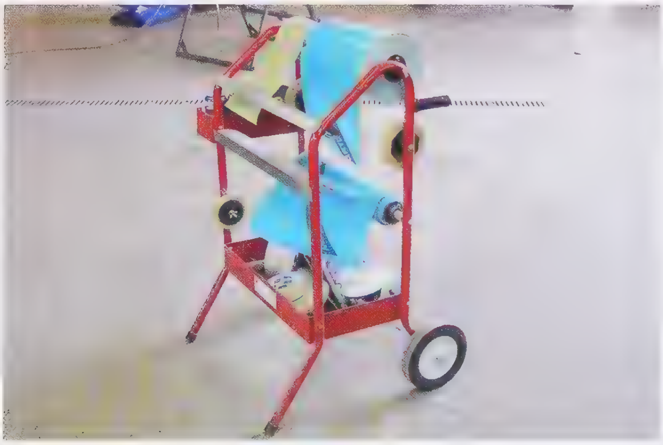


Figure 24-63. *This masking machine automatically applies masking tape to the edge of the masking paper as the paper is pulled off the roll.*

Pressure Washer

Clean vehicles are easier to work on. A ***pressure washer*** will easily remove dirt from a vehicle. One type of pressure washer utilizes a gas-powered engine to drive a high-pressure pump. The gas-powered pressure washer should be used outside only. Another type of pressure washer uses the shop compressed air system to produce high-pressure water. In some systems, the water can be heated and soap can be added. The pressure washer can also be used to clean out the spray booth.

Painting Platform

A ***painting platform*** is a low-rise aluminum scaffold designed to raise the painter high enough to access difficult-to-reach areas, such as the hood or roof of a vehicle. Painting is tough, physical work. A painting platform helps reduce painter fatigue and allows the painter to work faster.

Panel Positioners

For proper color match, panels, such as plastic bumper covers, may need to be repainted off the vehicle. See **Figure 24-64**. A ***panel positioner*** uses arms and chains to hold and orient the bumper cover in a way that duplicates its original position on the vehicle. Positioners are available for doors, fenders, and even pickup truck boxes.

Blasting Equipment

Blasting equipment shoots an abrasive media against a metal surface to effectively remove paint and rust. All blasting equipment uses a gun to direct and control the media. A replaceable nozzle concentrates the stream of media at the gun's outlet. As it travels through the gun, the media wears down the nozzle. Gun problems are usually due to nozzle wear.

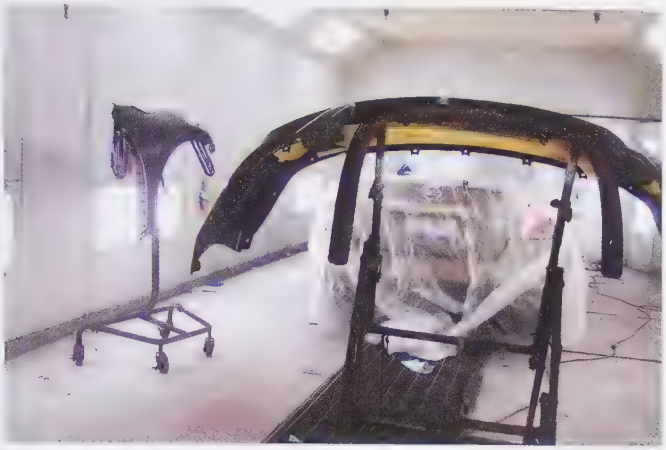


Figure 24-64. *Panel positioners are used here to hold a bumper cover and fender at the ideal angle during painting.*

Blasting a large area of sheet metal with an aggressive media, like sand, is not recommended. Friction generates enough heat to damage and warp thin panels. Blasting with aggressive media should be limited to very small areas (2 square inches or less) on thin panels.

Blasting produces harmful dust. Always wear a respirator when using blasting equipment, even when using a blaster designed to capture the media.

Siphon Blaster

A simple siphon blaster uses a stream of air to draw blasting media, such as sand, from a reservoir and shoot it against a surface. This system is very messy. It will scatter abrasive media throughout the work area. Therefore, this type of blaster should be used outside. The siphon blaster can be used for big jobs, such as stripping the underside of an antique vehicle.

Captive Blaster

A captive blaster consists of a gun that has a cup over the nozzle. The cup is pressed against a surface while the trigger is pulled. The nozzle is recessed inside the cup, and it's this feature that keeps the media from being blown all over. But when the job is done and the blaster is removed from the work surface, the spent media and dust will fall to the floor.

A tube conveys the abrasive media from a cloth bag to the nozzle. The hand-held captive blaster will clean a one-inch diameter circle. It is good for removing paint or weld-through primer in a plug weld hole in preparation for MIG welding.

Pressure Blaster

A pressure blaster consists of a pressure canister and a gun. See **Figure 24-65**. The canister is connected to compressed air, which forces the media through the gun. The amount of media mixing with the air determines the amount of paint or metal that is removed. This blaster does not recover media, so media is blown all over. Therefore, the pressure blaster should not be used inside the shop. The pressure blaster is suitable for large paint or rust removal jobs, such as a car frame.

Vacuum Blaster

A vacuum blaster combines a vacuum cleaner with a media blaster. The intake for the vacuum cleaner surrounds the blasting gun nozzle. As the gun is triggered, a vacuum pulls in the dust and spent media. This prevents much of the mess associated with sandblasting. The blasted area is larger than the area produced by the hand blaster. This system is useful for cleaning up a MIG weld.

Cabinet Blaster

For shops looking to minimize the mess associated with abrasive blasting, a cabinet blaster may be the solution. A cabinet blaster consists of a metal box with one or more doors and a viewing window. The blasting gun is located inside the box. Attached rubber gloves protrude into the cabinet, allowing the operator to simultaneously handle the part and the gun.

A siphon tube extends down into the media, which is stored in a reservoir at the bottom of the cabinet. Compressed air supply is controlled by a foot pedal. The blasting cabinet features a vacuum system to remove the dust and allow the operator to see inside the cabinet.

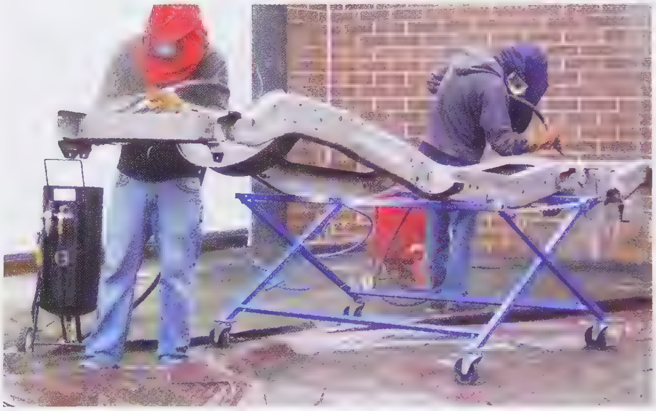


Figure 24-65. *A pressure blaster blows dust and spent media in all directions and should be used outside.*

The cabinet window is glass or plastic. Some media will rapidly etch the window, so a replaceable, clear plastic film is applied as protection.

Infrared Thermometer

An ***infrared thermometer*** is used to monitor the surface temperature of curing paint. The application of heat, from a baking spray booth or from infrared drying equipment, will accelerate the paint's rate of cure. A surface temperature of 140°F (60°C) is ideal, but the temperature must not exceed 200°F (93.3°C). Temperatures higher than 200°F (93.3°C) can cause the paint and underlying body filler to lose adhesion and blister.

To measure the temperature of curing paint, an infrared thermometer is pointed at the surface, a trigger is pressed, and a red dot of light indicates where the reading is taken from. See **Figure 24-66**. Adjust the distance between the heating equipment and the vehicle to maintain the proper surface temperature.

Paint Shaker

As the name implies, a ***paint shaker*** shakes, or vibrates, the paint can to thoroughly mix the paint. Both pneumatic and electric-powered paint shakers are available. The paint can lid must be tight before placing the can in the shaker. The can also must be tightly attached to the paint shaker. The paint shaker uses a timer to set shaking time. See **Figure 24-67**.

NOTE

Never shake water-based paint. Shaking water-based paint will put many small air bubbles into the paint.

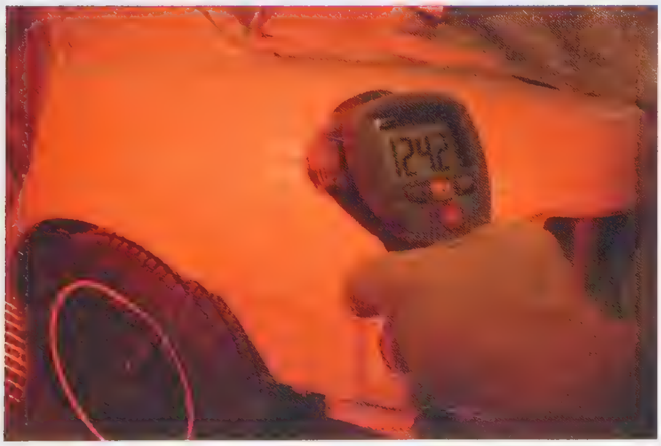


Figure 24-66. *Point the infrared thermometer at the heated surface and read the temperature.*

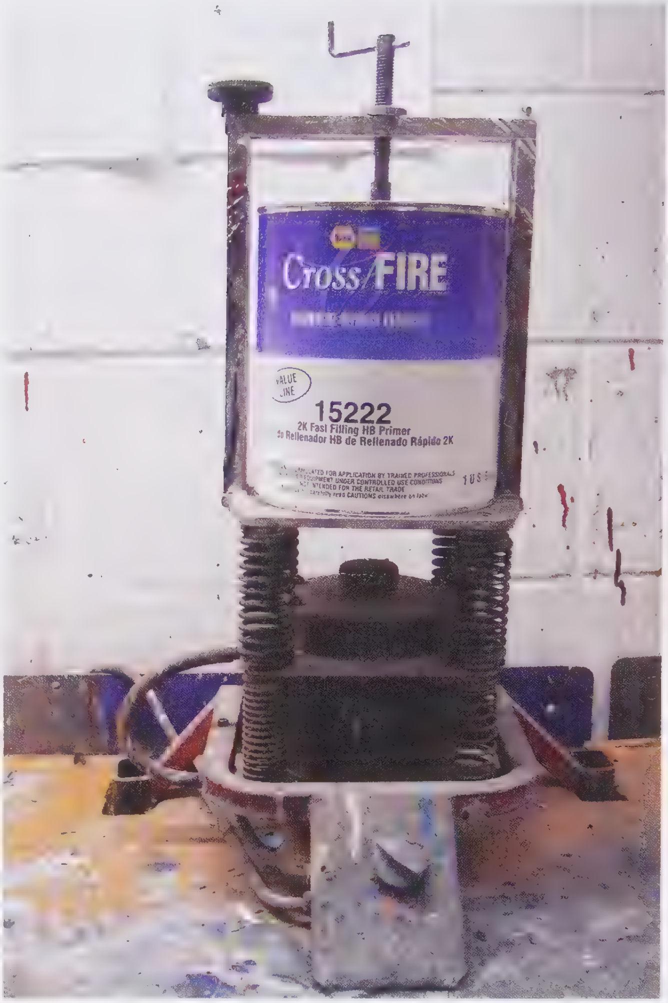


Figure 24-67. *Paint cans must be sealed and properly secured to the paint shaker to keep them in place during shaking. The shaker can be configured to hold gallon, quart, and pint cans.*

Powder Coating System

A ***powder coating system*** applies a charged, dry powder to grounded bare-metal parts. The gun imparts a positive electric charge on the powder and sprays it onto a grounded workpiece that literally attracts the dry, powdery coating. In an oven, the powder melts into a thick, uniform coating that doesn't run or sag, and is tougher than conventional paint.

A major advantage of powder coating is a 95% coating transfer rate and no VOCs. A simple powder coating system consists of a powder box, powder-coating gun, wire parts rack, and baking oven.

Summary

- Refinishing hand tools include tools for sanding and removing trim.
- Refinishing power tools include tools for sanding and buffing.
- Atomization is the breaking up of liquid paint into tiny droplets.
- Spray guns can be classified by the method of paint delivery—siphon-feed, gravity-feed and pressure-feed.
- Spray guns can be classified by air usage—conventional, HVLP, or LVLP.
- Spray-booths are classified by air movement—cross-draft, semi-downdraft and downdraft.
- Prep stations are used for sanding and, if allowed by local code, priming.
- Paint can be dried by hot air (140°– 200°F [60°– 93.3°C]); or infrared energy (long, medium or short wave).
- Spray gun cleaners reduce the amount of VOCs released during cleaning.
- The air compressor is the heart of the paint shop.
- Air compressors can be either piston or rotary screw.
- Water vapor can be removed from air lines by a refrigerated dryer or desiccant.
- Air pressure and volume are dependent on the diameter of pipes and hoses.

Review Questions

Please do not write in this textbook. Place your answer on a separate sheet of paper.

1. Sanding the surface to level out irregularities is called ______ sanding.
2. A(n) ______ spins a sanding disk in an oscillating pattern.
3. All buffers are powered by air. True or False?
4. Explain atomization.
5. On a spray gun the ______ is the on/off switch for air.
6. The ______ of the spray gun determines how much paint is discharged.
7. A mist is atomized paint. True or False?
8. Atomization takes place inside the air cap. True or False?
9. The fan pattern is produced by orifices in the ______.
10. The cup is above the air cap on a ______ spray gun.
11. In a ______ spray booth, the intake fan pushes in slightly more air than the exhaust fan removes.
12. A(n) ______ supplies air to the spray booth to compensate for the air that is discharged.
13. In a cross-draft spray booth, the air movement is from top to bottom. True or False?
14. The volume of air produced by an air compressor is measured in ______.
15. Explain how a two-stage piston air compressor works.

ASE-Type Questions

1. Technician A says that when used on its edge, a sanding stick can be used to block sand a high crown. Technician B says that a soft pad conforms to any contour. Who is right?
   (A) A only.
   (B) B only.
   (C) Both A and B.
   (D) Neither A nor B.
2. Technician A says a rough DA sander is used as a DA only. Technician B says that a rough DA sander can be used as a DA or as a grinder. Who is right?
   (A) A only.
   (B) B only.
   (C) Both A and B.
   (D) Neither A nor B.
3. All of the following are part of the paint path through a spray gun EXCEPT:
   (A) air valve.
   (B) cup.
   (C) needle.
   (D) fluid tip.
4. Atomization takes place ______.
   (A) at the tip of the needle
   (B) inside the air cap
   (C) at the air valve
   (D) outside the air cap
5. Technician A says that all pressurized spray guns have a remote cup. Technician B says that HVLP spray guns use less air pressure to atomize paint than conventional spray guns. Who is right?
   (A) A only.
   (B) B only.
   (C) Both A and B.
   (D) Neither A nor B.
6. Technician A says that a pressure-feed spray gun is useful for painting large areas. Technician B says that a plugged vent hole in a gravity-feed spray gun will not cause a problem. Who is right?
   (A) A only.
   (B) B only.
   (C) Both A and B.
   (D) Neither A nor B.

7. In which of the following spray booths is the air movement from top to bottom?
   (A) Cross-draft.
   (B) Semi-downdraft.
   (C) Downdraft.
   (D) Half-draft.
8. A spray booth has exhaust filters on each side of the booth. Technician A says this is a cross-draft booth. Technician B says this is a semi-downdraft booth. Who is right?
   (A) A only.
   (B) B only.
   (C) Both A and B.
   (D) Neither A nor B.
9. A spray booth has an exhaust fan only. Technician A says this is a positive pressure booth. Technician B says this is a negative pressure booth. Who is right?
   (A) A only.
   (B) B only.
   (C) Both A and B.
   (D) Neither A nor B.
10. Technician A says that a piston type air compressor has a 100% duty cycle. Technician B says that a piston air compressor runs cooler than a rotary screw compressor. Who is right?
    (A) A only.
    (B) B only.
    (C) Both A and B.
    (D) Neither A nor B.
11. The air pressure at which a piston air compressor shuts off is called the ______.
    (A) cut-out pressure
    (B) stop pressure
    (C) residual pressure
    (D) cut-in pressure
12. Which of the following protects the air compressor from dangerously high air pressures?
    (A) Air valve.
    (B) Pressure release valve.
    (C) Drain valve.
    (D) Piston.
13. Two technicians are discussing the air system in a shop. Technician A says that the piping should be looped to equalize pressure. Technician B says that the piping system should be made out of PVC plastic because it does not rust. Who is right?
    (A) A only.
    (B) B only.
    (C) Both A and B.
    (D) Neither A nor B.
14. Which of the following remove water vapor?
    (A) Regulator.
    (B) Desiccant.
    (C) Air compressor.
    (D) Particle filter.
15. At minimum, what is the internal diameter of air hose?
    (A) 1/8".
    (B) 1/4".
    (C) 5/16".
    (D) 3/8".

Chapter 25

Refinish Materials

Objectives

After studying this chapter, you will be able to:

- Understand the difference between thermoplastic paint and thermoset paint.
- List the types of paint commonly used to refinish vehicles.
- Describe the components of paint.
- Understand crosslinking and pot life.
- Explain the uses of primer, surfacer, sealer, basecoat, clearcoat, single-stage, and tri-coat.
- Identify the types of sandpaper used in refinishing.

Technical Terms

abrasive disks
abrasive pad
accelerator
additives
adhesion promoter
adhesion solvent
binder
bleeding
blending
bridging
buffing materials
build
catalyst
chemical resistance
closed-coat
crosslinking
curing
cutoff wheel
detail cloth
dilution solvent
dual-use undercoat
dust-free time
E-coat
etcher
fading
flattening agent
flash time
fish eye eliminator
flex agent
flexibility
flow out
grinding disk
hardener
hiding
hold out
hue-shifting colors
induction period
leveling solvent
liquid mask
mar resistance
masking paper
masking tape
mixing cup
mixing sticks
open-coat
oxidation
paint diluting elements
paint strainers
pigment
plastic wheel
polymerization
pot life
powder coating
pre-paint solvent
pre-sanding solvent
primer
reducer
reducing
retarder
rock guard
sanding paste
sealer
seam sealer
self-etching primer
shrink
solvent
solvent-borne paint
spray-on bed liner
stripping pad
substrate
surfacer
tack rag
thermoplastic
thermoset paint
thinning
topcoat
tricoat
undercoat
UV cure paint
viscosity cup
wash primer
waterborne paint

Introduction

The primary material used to refinish vehicles is paint. Paint is applied as a liquid. The wet portion of the liquid evaporates, leaving behind a solid film that is permanently attached to the vehicle.

There are many types of paint. Each is designed for a specific purpose. For example, the paint that forms the attractive and durable finish on a vehicle is called ***topcoat***. The topcoat has a distinct color and is resistant to weathering. Teaming up with the topcoat is the ***undercoat***. Undercoat is formulated to effectively adhere to the substrate and provide a satisfactory base for the topcoat. Some undercoats are used to fill nicks and scratches in the substrate. The ***substrate*** is the surface to be painted. In collision repair, the substrate may be steel, aluminum, body filler, rigid plastic, or flexible plastic. In addition to paint, there are many other materials used when refinishing a vehicle. These materials include cleaning solvent, sandpaper, masking materials, and buffing materials.

Types of Paint

Paint can be classified by how it dries, by the medium that carries the paint components, and by the application method. Paints used in the body shop dry in several ways, **Figure 25-1**. Some paints dry by evaporation of solvents only. These paints are called ***thermoplastic*** paints. Lacquer is a thermoplastic paint. After a thermoplastic paint is applied to a substrate, the solvents in the paint evaporate, causing the paint film to dry. **Figure 25-1A** shows how lacquer paint dries. If a strong solvent, such as lacquer thinner, is applied to the dried paint film, the solvent will turn the dried paint back into a liquid or at least soften the paint. Thermoplastic paints can be topcoats or undercoats. Thermoplastic topcoats dull as they dry, and must be buffed with a mild abrasive to produce a shine.

Enamel is ***thermoset paint***. It dries by evaporation of the solvent and by reaction. The reaction, also called ***curing***, could be by oxidation. ***Oxidation*** is a process in which the paint film combines with oxygen. See **Figure 25-1B**. The reaction could also be initiated by polymerization. During ***polymerization***, components in the paint react with each other. Polymerization can also be caused by the addition of a ***catalyst*** or hardener to the paint. Cured thermoset paint is more durable than a thermoplastic paint. The most commonly used paints in collision repair shops today are thermoset paints. Thermosets are used for both undercoats and topcoats. **Figure 25-1C** shows polymerization inside a catalyzed paint.

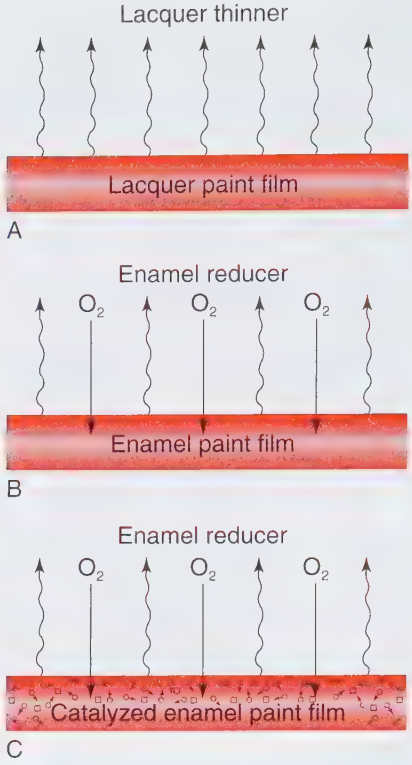


Figure 25-1. *A—A thermoplastic paint dries by evaporation of the solvent. The dried paint is not as durable as other types of paint. B—A thermoset paint dries by evaporation of the solvent and by reacting with oxygen in the air. C—A thermoset catalyzed paint cures by evaporation of the solvent, reacting with oxygen, and polymerization. Polymerization is the reaction of the hardener and the paint. This type of paint is more durable than other types of paint.*

Polymerization can also be caused by exposing the paint to ultraviolet (UV) radiation or heat. ***UV cure paint*** contains a photo initiator and is designed to cure, when exposed to UV radiation. These single-part paints are available as undercoats and clearcoats. No hardener is added to the paint.

UV cure paints cure completely in five minutes or less, regardless of temperature, humidity, or airflow. The paint must be in direct line with the curing lamp to totally absorb UV radiation. Portions of the paint not in direct line with the lamp, such as areas shaded by a protruding part, do not fully cure. To reach and effectively cure all painted areas, the UV curing lamp must be moved and repositioned. Some brands of UV paint can cure in sunlight, but a UV curing lamp is more efficient because it is easier to move a lamp than a vehicle. The paint manufacturers' recommendations for cure time and UV lamp wattage must be followed closely, as over-curing may prevent the proper adhesion of subsequent paint coats.

Another way to cure paint in automotive applications is with heat. An example is powder coating. In ***powder coating***, the paint is not a liquid, but a powder. The coated part is baked at high temperature to cure the powder. The powder melts and flows to create a glossy, durable surface. Powder coating is a specialty paint usually applied to individual parts and not an entire vehicle.

Another way to classify paints is by the medium that carries, or suspends, the paint components. A ***solvent-borne paint*** uses highly volatile chemicals, such as ether, to carry the paint components. When these chemicals, known as volatile organic compounds, or VOCs, evaporate, they become a health threat to the technician and create air pollution. Most of the refinish paint used in collision repair shops is solvent-borne paint.

Paint components in a ***waterborne paint*** are suspended in water. Although a waterborne paint does contain some volatile solvent, it is not nearly as much as is found in a solvent-borne paint. A waterborne paint causes less air pollution, in the form of VOCs, than a solvent-borne paint. Waterborne basecoats are now commonly applied to vehicles in collision repair shops. In certain parts of the country it is illegal to use anything but waterborne paint.

Application method is the final way to classify paint. Most body shops use a spray gun to apply paint, and most automotive paint is designed for spray gun application. Using a spray gun usually requires that the vehicle be masked and moved to a spray booth. After painting, the spray gun must be cleaned. Aerosols and roll-on paints are designed to save time on masking, moving, and cleaning. Aerosol paints offer many advantages for small repairs: no mixing is required, minimal masking, the vehicle does not need to be moved to a spray booth, there is no spray gun to clean, and there is no leftover paint (hazardous waste) to dispose of. Types of aerosol paints include self-etching primer, surfacer, plastic adhesion promoter, single-stage color, and clearcoat. Some aerosol undercoats are designed for UV curing.

Aerosol paints have many uses in a body shop. The easy-to-use aerosol can uses butane to propel and spray the paint. Most aerosol paints are one-part acrylic lacquer or acrylic enamel, but some two-part aerosols are available. The two-part aerosols are packaged in a can that features two separate compartments: one for paint and the other for hardener. Pushing down on the spray head releases the paint and hardener. The two components mix in the spray head.

Roll-on application requires paint mixing but no masking or moving the vehicle. The applicator is disposable. Lining the tray with aluminum foil eliminates cleanup. Roll-on undercoat is mixed without reducer. The roller should be moved in one direction only when applying the undercoat. Ridges on the edges of the undercoat can be eliminated by rolling over and smoothing. Apply one coat to fill the featheredged area. Then apply another, slightly larger coat over the first coat. Roll-on undercoat application is not as smooth as spray gun application and will require additional sanding to smooth the surface.

Paint Components

The following section describes components that are combined to make paint. Paint is very specialized. Each type of paint is designed for a specific purpose, such as binding to bare metal, filling scratches, preventing rust, promoting adhesion, protecting from UV radiation, and providing color.

The chemical composition of the paint will vary, depending on its purpose. The components of paint are binder, pigment, solvent, and additives. See **Figure 25-2**. The binder, pigment, and additives are solids, while the solvent is liquid.

Binder

The ***binder*** is considered to be the backbone of the paint. Dried paint is referred to as a paint film and the binder creates the paint film. Binders are thick resins that, when mixed with solvent, form a matrix to evenly disperse and contain the paint's pigment.

The type of binder used determines the paint's durability, as well as curing characteristics. There are many different binders used in paint: acrylic, urethane, epoxy, polyester, polyurethane, and acrylic urethane. Each one of these binders is used to make a specific type of paint.

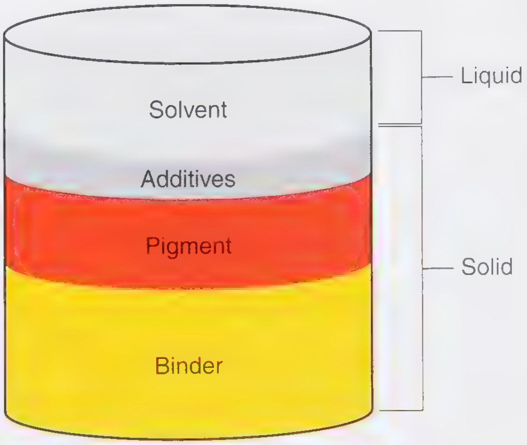


Figure 25-2. *The components of paint are the binder, pigment, additives, and solvent.*

Pigment

Pigments are made from fine powders and determine the color of the paint. All paints except clearcoats and UV-cure paints contain pigment. Various pigment colors are combined in predetermined ratios to produce the desired color. Common pigments include titanium dioxide, which produces a white color, and iron oxide, which creates a red color.

Pigments also determine how well a color hides. ***Hiding*** is a measure of how well the paint masks the color it is sprayed over, and how well it displays the true color of the paint without influence from the color underneath. A good hiding color will mask a gray undercoat in two coats, while a poor hiding color will still show some of the underlying gray undercoat after two coats.

In some cases, a pigment known as magnesium silicate, or talc, is used to add bulk to paint, allowing it to fill surface scratches. Some pigments add durability or corrosion resistance to the paint film.

Aluminum flakes and mica are topcoat-only pigments. Aluminum flakes give the paint a metallic effect. This effect is caused by light reflecting off the mirror-like surface of the aluminum flakes. The size of the flakes can range from very small to large. Aluminum flakes can be polished on both sides so that both sides can reflect light. Some flakes are polished only on one side. Paint with flakes polished on both sides looks brighter than paint with flakes polished on one side only.

Mica added to paint gives a pearlescent effect. The mica allows some of the color of the paint to show through. The pearlescent effect is more subtle than the metallic effect. Aluminum flakes and mica may be combined in some types of topcoat.

Solvent

The binder is a thick resin, while pigment is a dry power. A ***solvent***, added to a mixture of binder and pigment, results in a workable liquid. The solvent dissolves the binder and carries the pigment. Some of the solvents in solvent-borne paint include ether, toluene, xylene, and acetone. In waterborne paint, the solvent is water, which is blended with other water-soluble solvents.

Solvent will evaporate if exposed to air, leaving behind a solid paint film. For this reason, always keep the lid tightly sealed on any stored paint.

Additives

Additives are used to give paint special capabilities or to prevent problems. For example, after paint is sprayed it must stay wet long enough to flow out and create a level film layer. So an additive, called a flow agent, is mixed into the paint to enhance its ability to flow and level out.

Another additive is UV screener. UV radiation from sunlight can damage automotive paint. UV screener prevents or delays the damage caused by UV radiation. Anti-gelling additive will prevent the development of insoluble polymers in the resin during storage. The formation of insoluble polymers changes paint into an unusable jelly. An anti-blistering agent prevents the formation of blisters, or bubbles, in the cured paint. Blistering is typically caused by water or acids trapped under the paint.

One way to think of paint is to consider the binder as chocolate syrup, the pigment as chocolate powder, the solvent as milk, and the additives as sugar. The milk dissolves the syrup and keeps the chocolate powder and sugar in suspension.

WORKING GREEN

To reduce air pollution, paints have been formulated to minimize the amount of solvent they contain. High-solids paints contain more than 50% solids by volume, or more than 62% solids by weight. The solids are the binder, pigment, and additives. Reducing the amount of solvent in the paint reduces the amount of VOCs released into the air. High-solids paint is common in today's collision shops.

Paint Diluting Elements

Some types of paint, such as waterborne primer-surfacer, are packaged ready-to-spray. Most paint, however, must be diluted before spraying. ***Paint diluting elements*** are mixed into the paint by the body shop technician.

Some paint diluting elements, such as thinner or reducer, are combined with paint to create a sprayable mixture. Other paint diluting elements include catalysts for crosslinking, special-use additives, and performance additives. See **Figure 25-3**.

Dilution Solvents

Viscosity is the measurement of a liquid's thickness. A ***dilution solvent*** is used to dissolve a thick paint down to a sprayable viscosity. Lacquer paint is diluted with thinner. This process is called ***thinning***. Enamel paint is diluted with reducer, a process known as ***reducing***. Adding reducer or thinner decreases the viscosity of paint. Viscosity is determined by counting the number of seconds it takes for a specific volume of paint to flow out of the hole in a viscosity cup. A ***viscosity cup*** holds a measured amount of paint. A precisely sized hole in the

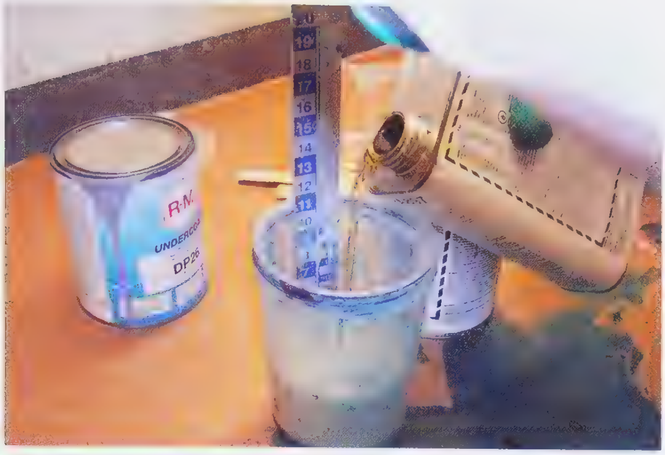


Figure 25-3. *Adding catalyst to paint will cause crosslinking.*

bottom of the cup allows paint to flow out. Thicker paint takes longer to flow from the cup than thinner paint. **Figure 25-4** shows a viscosity cup.

Reducing

Reducing will be discussed in detail because most collision repair shops only use enamel paints. A ***reducer*** is a blend of solvents. These solvents can be divided into three categories:

- ***Dilution solvent***—The reducer component used to dilute the paint to a sprayable mixture. This solvent evaporates as the paint mixture is sprayed. This is the fastest evaporating component of the reducer.
- ***Adhesion solvent***—The reducer component that chemically bites into the substrate. Once the paint is sprayed on a substrate and the adhesion solvent bites in, this solvent evaporates.
- ***Leveling solvent***—The reducer component that causes the paint film to stay wet long enough for leveling to take place. ***Flow out*** is the ability of the wet paint film to level to a smooth surface. The ***leveling solvent*** is the slowest evaporating component of a reducer.

Reducer evaporation plays a major role in paint drying. The speed at which reducer evaporates from the paint film depends on spray booth temperature, airflow, and paint film thickness. See **Figure 25-5**. Spray booth temperature, in some climates, is dependent on the ambient temperature. In a cold climate, the air entering the spray booth must be heated to at least 60°F (15.5°C). Warmer temperatures cause paint to dry faster, sometimes too fast to allow for proper paint flow out. When the ambient temperature is above 60°–70°F (15.5°–21°C), a reducer is added to the paint mix to control the rate of cure. The type of reducer used to dilute the paint will determine how long the paint stays wet after spraying.

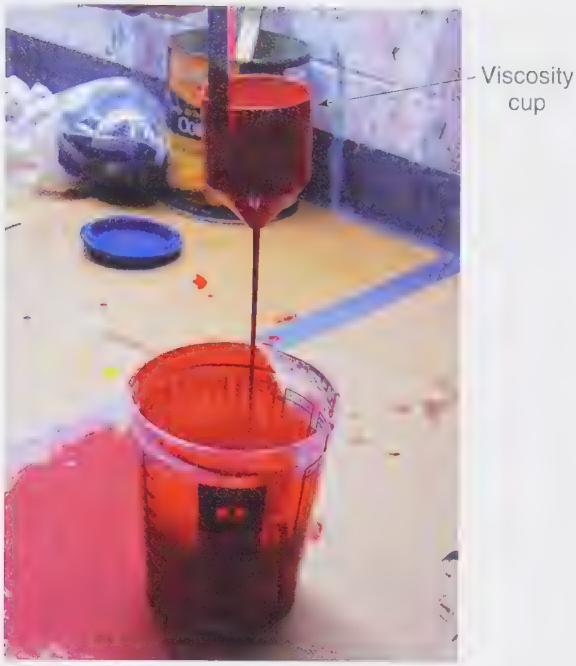


Figure 25-4. *The viscosity of paint is measured with a viscosity cup.*

Variables and Their Effect on Cure Time

Variable	Effect on Cure Time
higher temperature	decrease
lower temperature	increase
more airflow	decrease
less airflow	increase
greater paint thickness	increase
lesser paint thickness	decrease

Figure 25-5. *Several variables will affect cure time.*

Airflow, or how much air moves over the vehicle, is determined by the speed of the spray booth fans and how quickly the air can move through the spray booth filters. Greater airflow causes the reducer to evaporate faster; less airflow causes reducer to evaporate slower.

Paint film thickness, which is dependent on the number of coats of paint applied during a period of time, also determines the rate at which reducer evaporates. Thick paint, where the reducer must travel through several overlying coats, causes a slower evaporation rate.

Paint can be applied thickly by spraying two or more coats with little or no dry time in between coats.

Thin paint, where reducer only needs to travel through one coat, results in a faster evaporation rate. Paint can be applied thin by spraying one coat then waiting for the solvent to evaporate before applying the next coat.

Various types of reducers are available that will evaporate at different rates. This allows the paint to perform consistently in different environments. The types of reducers are often referred to as low-temperature, mid-temperature, and high-temperature reducers. A low-temperature reducer evaporates rapidly; a high-temperature reducer evaporates slowly.

For consistent results, match the reducer to the conditions in the spray booth. If the reducer and spray booth are mismatched, paint will not perform properly. For example, if a high-temperature reducer is used in a cold shop with a spray booth temperature of 65°F (18.3°C), the solvent will not evaporate fast enough. The paint will stay wet too long, possibly causing runs or more serious problems. Similarly, if a low-temperature reducer is used in a 90°F (32.2°C) spray booth, the paint will dry too fast. The solvents will evaporate before the paint film can flow out, causing the paint film to look rough. Always select an appropriate reducer based on spray booth temperature. See **Figure 25-6**.

Waterborne base coat may need to be reduced before spraying. One brand of waterborne base coat requires different reduction with distilled water depending on the humidity in the spray booth. In humid air the reduction ratio is 5%, in medium humidity the reduction rate is 10%, and in dry air the reduction rate is 15%. Another brand of waterborne base coat requires a mixing ratio of 2 parts base coat to 1 part waterborne reducer.

Match Reducer to Spray Booth Temperature

Solvent	Spray Booth Temperature Range
Low temperature reducer	60° to 70°F
Mid-temperature reducer	70° to 85°F
High-temperature reducer	85° to 95°F

Figure 25-6. *Always match the reducer to the spray booth temperature.*

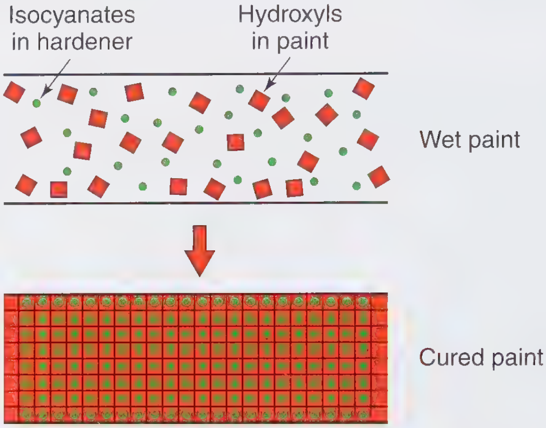


Figure 25-7. *The reaction of hydroxyls in the paint and isocyanates in the hardener cause the two-part paint to cure.*

Hardener

Many paints used today are mixed with a paint hardener. A ***hardener*** causes crosslinking, which makes the paint durable. ***Crosslinking*** is a chemical reaction between the resin and hardener. The resin contains hydroxyls, while the hardener contains isocyanates. The reaction between hydroxyls and isocyanates, shown in **Figure 25-7**, is crosslinking. Paints that require a hardener are described as two-part or 2K paints.

Isocyanates are toxic chemicals and an individual exposed to them may have a physical reaction. In some cases, isocyanates cause severe respiratory distress. Always take proper precautions when mixing or spraying isocyanates.

NOTE

Precautions for working with isocyanates were covered in Chapter 2, Safety.

Pot life is the amount of time it will take for the mixed paint to cure under standard conditions of 70°F (21°C) and 50% humidity. Curing starts as soon as the hardener and paint are mixed. Even if the paint is not sprayed, it will cure. Pot life will be listed on the paint can or in the refinish manual.

Shop temperature affects the cure time of sprayed paint. Again, the standard is 70°F and 50% relative humidity, assuming there is sufficient airflow to remove overspray. A temperature greater than 70°F will reduce cure time. In a spray booth that is 85°F (29.4°C), the cure time may be reduced by as much as 50%. A temperature below 70°F will increase the cure time. Also, a temperature below 60°F is too low for crosslinking to occur. If the painted vehicle is not kept above 60° for two to three hours after it is painted, the paint may never cure properly. The paint may dry, but crosslinking will never take place. This will cause the paint to appear dull and have less durability.

Hardeners are rated by wet time, which is the length of time the surface will remain wet enough to accept overspray. A wet surface will allow overspray from adjacent panels to melt in. When painting a single panel, a short wet time is desirable because adjacent panels will not be painted, so there is no need for the paint to stay wet. However, when painting multiple panels or an entire vehicle a longer wet time is desired. This is because the paint surface must stay wet long enough to allow overspray from adjacent panels to melt in. Clearcoat hardeners are available in single- or multiple-panel varieties.

Once a can of hardener is opened, it has a shelf life. Shelf life is the amount of time that an opened product, even when resealed, will remain useable. Moisture in the air will cause the hardener to deteriorate over time, so use hardener within seven days of opening. Mark the opening date on the can of hardener. A hardener that has turned to a solid is, of course, unusable. If the container has been opened for more than seven days, even if the hardener is still liquid, expect problems such as graininess and poor adhesion.

Special-Use Additives

Special-use additives are used by the paint technician to modify the characteristics of paint. For example, adding a ***flex agent*** changes the paint by allowing it to remain pliable when deformed. Some types of body parts, such as a urethane bumper cover, are designed to absorb impact with no damage. The paint film must be capable of deforming without cracking when the bumper cover is distorted during an impact See **Figure 25-8**.

The paint on most interior parts is not glossy. The degree of gloss or shine of paint can be modified by adding a flattening agent. A ***flattening agent*** reduces the gloss level, depending on how much is added.

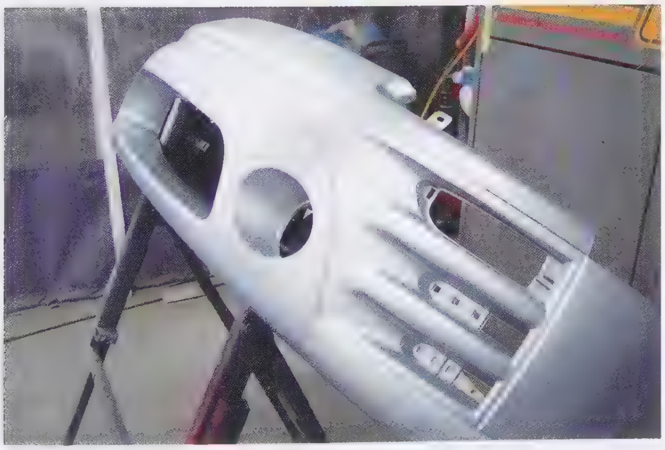


Figure 25-8. *This flexible bumper cover will be painted with a clearcoat. The clearcoat will have a flex agent added to it.*

Fish eyes result from spraying paint over surface contamination such as oil or silicone. The contamination repels paint so it cannot adhere, resulting in an unpainted depression at the point of contamination. ***Fish eye eliminator*** changes the chemistry of the paint to be similar to the chemistry of the contamination, so the paint is attracted to, not repelled by, the contamination. Fish eye eliminator can be added to paint if a fish eye problem shows up while spraying. If fish eye eliminator is used, all subsequent coats should also use fish eye eliminator. If the vehicle is refinished again, fish eyes will show up in the new paint unless fish eye eliminator is added to the paint.

NOTE

Fish eye eliminator cannot take the place of good surface cleaning. It is much better to prevent fish eyes through proper cleaning than it is to spray over them with fish eye eliminator additive in the paint.

Performance Additives

Very hot temperatures (100°F or above) cause paint to dry much too fast, even when using a high temperature reducer. Performance additives are used to more accurately control the rate of cure. A ***retarder*** is used to lengthen paint drying time, causing the paint to flow out more. A retarder is added as a percentage of total reduced paint volume. Retarder should never make up more than 10% of the total reduced paint volume and it should only be added to topcoats. An ***accelerator*** can be added to paint when a faster drying time, or cure time, is needed. Undercoats may be accelerated to reduce cure time and speed the repair. Accelerators are added as a percentage of total reduced paint volume, or as a part in a ratio. In addition to cure time, an accelerator will also decrease the pot life of the paint.

Topcoats

Topcoats are what you see when looking at a vehicle. The topcoat provides color, and because of exposure to the elements, it must be extremely durable. UV radiation will degrade paint, making the color appear pale and washed out. Changing color is called ***fading***, and is caused by the breakdown of pigment from the UV radiation in sunlight. A durable paint has a chemical composition that resists UV radiation.

The breakdown or gradual erosion of the binder in paint is called chalking. As the binder breaks down, powdery particles of paint are released. With enough exposure to sunlight, all the paint will eventually break down and wear away. See **Figure 25-9**.

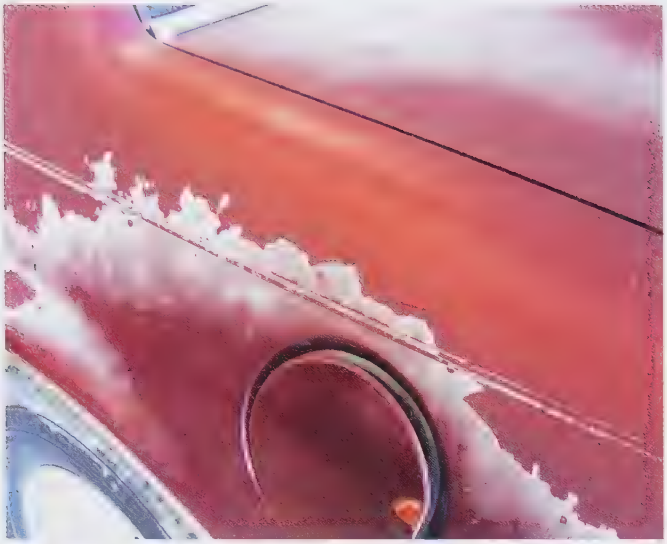


Figure 25-9. *The binder in this clearcoat has turned to powder. The red base coat has faded in areas where it is not protected by the clearcoat.*

Chemical resistance is an important aspect of durability. A durable paint will not dissolve or stain when a solvent, such as gasoline, is spilled on it. Acid rain is caused by a form of air pollution that tests a vehicle's chemical resistance. As the water in acid rain evaporates from a vehicle's surface, the remaining acid, now more concentrated because the water is gone, pits or etches the paint.

Flexibility is another desirable characteristic of a durable paint. Metal will expand as the vehicle is heated by sunlight and then contract when it cools off. The paint must be flexible enough to move with the metal's expansion and contraction cycles. If the paint is inflexible, it will crack. Chip resistance is a by-product of flexibility. A flexible paint does not readily crack or chip from a minor impact.

The final attribute of a durable topcoat is ***mar resistance***. Mar resistance means that the paint is hard enough that it is not easily scratched by abrasion. Paint with a strong attraction between the binder and the additive is mar resistant. However, the components in paint that make it mar resistant also make the paint inflexible. Paint must be engineered to balance mar resistance and flexibility. Topcoats are classified as single-stage paints, basecoat/clearcoat paints, and tricoats.

Single-Stage Paints

Single-stage paint consists of color only. Single-stage paint is not used much in collision repair today. However, it is used for fleet and equipment refinishing. The pigment in single-stage paints may be solids, producing a solid color, as well as aluminum flakes, which produce metallic paint. Types of single-stage paints include:

- Nitrocellulose lacquer—An obsolete paint that may be used for restorations. This type of paint was applied at the factory to new vehicles in the 1920s through the 1950s. Nitrocellulose lacquer paint is high in VOCs. This type of paint is not readily available in all areas of the United States. Nitrocellulose lacquer paint may be selected by a restorer to maintain the authenticity of a restored vehicle. See **Figure 25-10**.
- Acrylic lacquer—Another type of obsolete paint that is not as durable as enamel. It must be buffed to achieve gloss. Acrylic lacquer dries quickly. Fast-drying paint has a short dust-free time. This is a big advantage in a dirty shop. Acrylic lacquer is more forgiving than enamel, and because it dries quickly it is less likely to run. If the lacquer paint does run or if there are other application problems, the mistakes can be sanded out once the paint dries—usually a matter of minutes—and spraying can continue. Acrylic lacquer paint is also high in VOCs.
- Synthetic enamel—Also called alkyd enamel, synthetic enamel, has a polyester resin binder. The pigment in this type of paint fades rapidly. It is generally used for equipment and fleet refinishing where repaints are frequent. Synthetic enamel can be mixed with a hardener and it flows out well. However, it is not available in OEM colors.
- Acrylic enamel—Offers good durability when mixed with a hardener. Acrylic enamel is made with an acrylic binder. Available in OEM colors, acrylic enamel is most useful for a complete repaint.

Figure 25-10. *Older vehicles were originally painted with nitrocellulose lacquer.*

- Polyurethane enamel—Primarily used to paint semi trucks and equipment. This type of paint is very durable. Not available in OEM colors.
- Acrylic urethane enamel—Durable finish available in OEM colors. This type of paint is most useful for a complete repaint. See **Figure 25-11**.

Basecoat/Clearcoat Paints

Urethane basecoat/clearcoat paint is the preferred topcoat for most collision repair shops. Basecoat/clearcoat simplifies ***blending***, which is the ability to hide slight color variation, or mismatch, between the repaired panel and the rest of the vehicle. Acrylic lacquer paint is available as basecoat/clearcoat.

In a urethane basecoat/clearcoat system, the basecoat is made from acrylic or polyester resin. The pigment may consist of solids, as well as aluminum flakes, or mica. The basecoat is diluted with a reducer. Some brands of paint also use a hardener in the basecoat. The hardener causes the basecoat to cure and to have a pot life.

The basecoat applied to cover the substrate is about 1 mil (0.001") thick. Some types of basecoat have poor hiding capabilities. See **Figure 25-12**. Any color that contains red pigment will be a poor hider. Pearls are also poor hiders. The basecoat will dry to a dull finish, and is not sanded prior to the application of clearcoat. The clearcoat must be applied to the basecoat within a specified time window. This time window varies with the brand of paint but it is usually acceptable to apply the clearcoat from 1/2 hour after basecoat application to 24 hours after basecoat application. After 24 hours, the basecoat will not accept the clearcoat. The basecoat would have to be sanded and reapplied before clearcoat could be sprayed.

Figure 25-11. *This SUV has been repainted with acrylic urethane.*

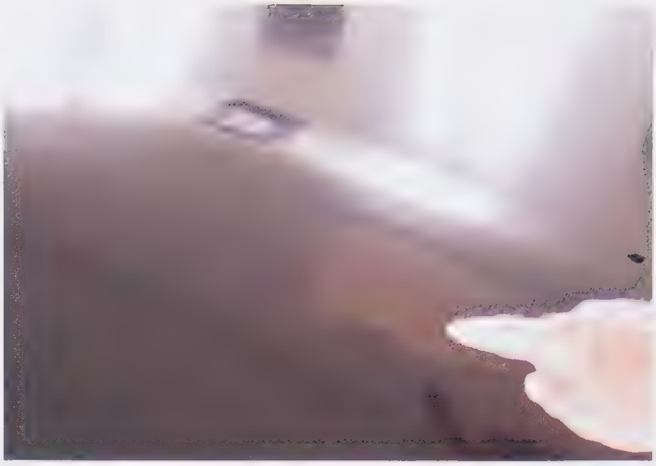


Figure 25-12. *Hiding is the ability of a color to cover up the underlying paint color. Note that the gray undercoat shows through this black basecoat. Additional coats of black are needed to cover and hide the undercoat.*

The clearcoat usually contains no pigment, although some tinted clears are available. Most clearcoats are mixed with a hardener. The clearcoat brightens the basecoat, providing durability and depth. Clearcoat must be at least 2 mils thick for durability. The different types of clearcoats include:

- Fast-dry clear—this type of clear has a ***dust-free time*** of approximately two minutes. Dust-free time is the amount of time, in minutes, from the application of the paint until the paint is dry enough that dirt particles will not stick to it. A fast-dry clear stops flowing so quickly that there is not much time for leveling. The cured clearcoat will look the same as when it was sprayed. Fast-dry clear is used to paint single panels or just a section of a vehicle.
- Medium-dry clear—has a dust-free time of approximately five to ten minutes. This type of clear has time to level and smooth out before it dries. However, a longer dust-free time increases the chance for airborne dirt to land in the paint. Medium-dry clearcoat is known as a general use clearcoat. It can be used on single panels, multiple panels, or a complete paint job. This clearcoat will run if too much is sprayed on. Because the paint has time to level, a run may appear up to ten minutes after spraying.

- Slow-dry clear—is used primarily on complete repaints or multiple panels in a downdraft/baking spray booth.This clearcoat may take as long as 20 minutes before it is dust free, and runs can form up to 20 minutes after application. Due to the long leveling time, this clearcoat will have more gloss than the other types of clearcoat if properly sprayed in a dust-free spray booth.
- Blending clear—when premixed with slow-dry reducer it is used to melt-in dry overspray.
- Cut-in clear—used when trimming parts or painting any area that will not be exposed to sunlight. This clearcoat comes from the manufacturer ready to spray, saving mixing time.

Tri-Coat Paints

A ***tri-coat*** is similar to basecoat/clearcoat in that the last coat is clear. In a tri-coat, however, there are two layers of paint underneath the clearcoat. In one type of tri-coat, the first layer is a solid base color. This is the same as basecoat in a basecoat/clearcoat application. It is reduced and, if necessary, hardener is added. The middle layer in a tri-coat is a translucent pearl. The pearl coat allows the color of the base to show through. The pearl coat is also reduced and hardener may be added, depending on the brand of paint. There may be as many as three coats of base, three coats of pearl, and three coats of clear. See **Figure 25-13**. Another type of tri-coat uses a metallic basecoat and a translucent pearl mid-coat. The clear may or may not be tinted.

Hue-Shifting Colors

Hue-shifting colors are found on some OEM vehicles. These are tri-coat finishes. What sets them apart from conventional tri-coat paints is the nature of the pigment. The pigment particle consists of an aluminum layer in the center. See **Figure 25-14**. Surrounding the aluminum is a layer of magnesium fluoride. This glass-like layer refracts light similar to a prism. On top of the magnesium fluoride layer is a thin coating of semi-transparent chrome. The thickness of the magnesium fluoride layer determines the range of colors seen when viewing the painted surface from different angles. For example, the color can appear red when viewed from one angle and gold when viewed from another angle.

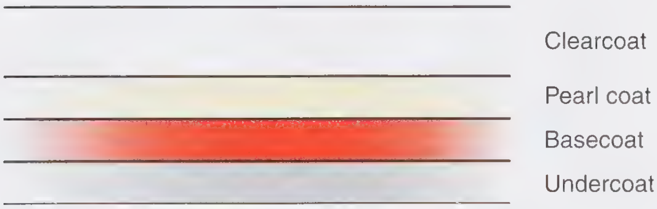


Figure 25-13. *A tri-coat consists of an underlying basecoat, an intermediate pearl coat, and an overlying clearcoat.*

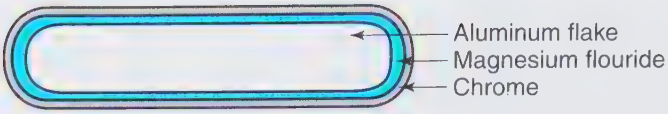


Figure 25-14. *The magnesium fluoride layer refracts light.*

Paint manufacturers combine these pigment particles with aluminum, black, or other solid pigments to create the wide variety of hue shifting colors. Spraying these colors is the same as spraying other metallic basecoats. A solid base color is sprayed first, followed by the hue shifting color, and then the clearcoat. Choice of base color will influence the hue-shifting effect.

Specialty Topcoats

Today's technician may be called upon to repair and refinish more than just the exterior finish. Often, due to collision damage, frame and suspension components, engine compartments, trunks, and truck beds require repair.

Powder Coating

Powder coating does not produce VOCs; therefore it is likely that its use will increase in body shops and specialized refinishing shops. A special coating gun sprays electrostatically charged dry powder onto a grounded, bare metal part as shown in **Figure 25-15**. The part attracts the powder, due to the attraction of opposite charges. The powder clings to the part but is not tightly bound to the part until heated to 400°F (204°C) in a baking oven. Heating the powder literally melts and flows it into the pores of the metal as it cures. Curing takes about 20 minutes. The cured powder coat is durable, shiny, and strongly bonded to the metal.

Single-stage, solid or metallic, and basecoat/clearcoat powders are available. The powder can be thermoset or thermoplastic. Crosslinking during heating cures the thermoset powder coating.

A thermoset powder coating should not be reheated to curing temperatures after initial curing. A thermoplastic powder coating does not crosslink during curing. Thermoplastic powder coating, when reheated to curing temperature after curing, will reflow. The size of a part that can be powder coated is limited by the size of the baking oven,

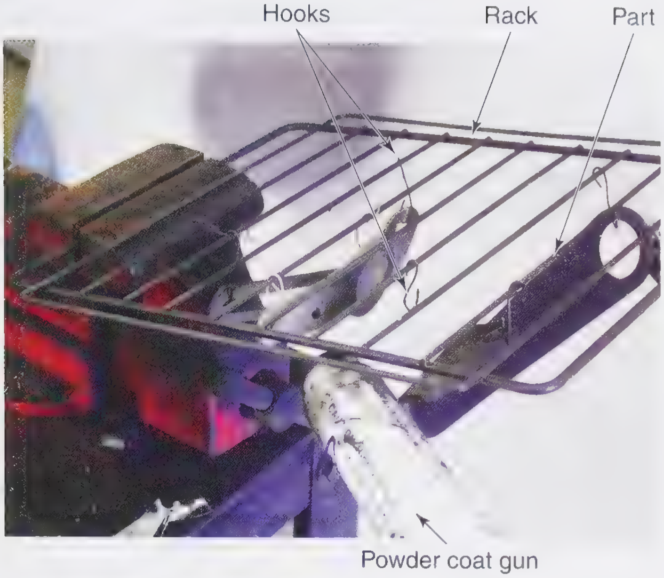


Figure 25-15. *The powder coat gun is applying charged powder to bare metal parts. The part on the right has already been coated with powder. The parts are hung on a wire rack that will be placed into a 400°F oven to bake on the powder coat.*

although some shops use an infrared lamp to cure large parts. The advantage of powder coating is that no VOCs are produced and the finish is extremely durable. The disadvantage is that the part must be heated to 400°F (204°C) for curing. Parts that can be powder coated include brackets, engine valve covers, and truck rear bumpers.

Spray-On Bed Liner

The paint on the inside of a pickup truck bed is expected to endure abuse. A ***spray-on bed liner*** is engineered to further protect the paint inside the truck bed, **Figure 25-16**. The spray-on bed liner is a urethane-, polyurethane-, or epoxy-based polymer. The most common color is black, but it can be tinted to match the vehicle color.

Before the bedliner material can be applied, the paint in the bed must be sanded and primed with a special adhesion promoter. There are several companies that offer this product. Some manufacturers require a special gun that mixes the polymer and hardener at the gun outlet. Other manufactures use a polymer that can be mixed with hardener and applied with a spray gun or a roller. Body shops may apply the spray-on bed liner as a supplement to collision repair. If a panel of a bed already coated with spray-on bed liner is replaced, the bed liner material will need to be reapplied. The spray-on bed liner is tough and may be extremely difficult to remove.

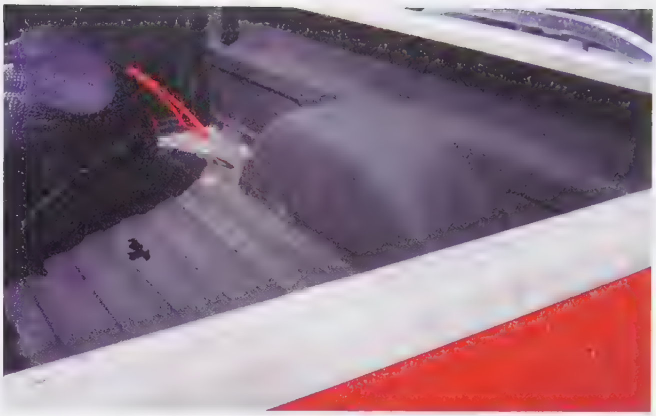


Figure 25-16. *The spray-on bed liner protects the inside of the truck bed from scrapes in the paint. Notice that this bed liner has faded. It is no longer glossy black.*

Undercoats

Although undercoats are hidden by the topcoat, they are very important. The appearance of the topcoat is dependent on good surface preparation and proper undercoat application. This section explains the different types of undercoats.

Etchers

Moisture in the air will cause rust to form on bare steel. At first, this rust formation is so small that it's virtually invisible, but it begins to form the moment bare steel is exposed to air. ***Etchers*** are used to remove this microscopic rust formation and to prepare the bare steel to accept paint. Preparing metal in this way is a two-step process that involves cleaning and phosphating. The first step is to clean the steel with a mild acid, and the second step is to deposit zinc phosphate on the bare steel. Taken together, these two steps are called etching. The cleaning and phosphating can be performed by separate products or by a single component that can do both jobs.

Cleaning

Microscopic rust is removed by cleaning bare steel with a phosphoric acid solution. See **Figure 25-17**. The solution, sometimes called metal prep, is made up of one part acid combined with two parts of water. Scrub the bare metal with a nylon scuff pad coated with the acid/water solution. One paint manufacturer recommends that the acid/water mixture be applied to bare steel, allowed to work for about 3–5 minutes and then wiped off.

Figure 25-17. *An acid solution is used to remove rust.*

Another manufacture suggests rinsing the panel with water after acid treating. All manufactures state that the acid/water solution should not be allowed to dry while working the surface. If the acid/water does dry while working, you will have to start over. Do not use the acid/water solution if the surface temperature is below 60°F (15.5°C).

Phosphating

To prevent corrosion and to prepare the surface for maximum primer adhesion, a layer of zinc phosphate crystals are deposited on the bare steel. This zinc phosphate layer is sometimes called a conversion coating. The conversion coating is applied directly from the container. No mixing is required. The application is similar to an acid/water mixture in that the surface is kept wet for three to five minutes. See **Figure 25-18**. A nylon scuff pad can be used to work in the solution. After allowing sufficient time for the coating to do its work, rinse with water. While washing the panel, the rinse water should not bead; the water should flow off the panel with no breaks. A break or bead indicates improper zinc phosphate coverage. Retreat the panel if breaks or beading occurs.

Figure 25-18. *The conversion coat deposits phosphate crystals on the cleaned metal.*

CAUTION

Do not use this cleaning/phosphating process under polyester body filler or polyester primer. Polyesters cannot properly adhere to the treated surface.

Bare aluminum will oxidize, forming a clear, dull layer called aluminum oxide. This layer of contamination will prevent good paint adhesion. Bare aluminum should be treated with a cleaner and a conditioner prior to primer application. These products are designed specifically for cleaning aluminum. Do not treat aluminum with an etcher formulated to clean steel.

Primers

Metal must be clean and free of oil. Do not touch bare metal as oil from the hands will contaminate the metal. The oil residue from touching bare metal will interfere with the primer-to-metal bond. ***Primer*** is applied to metal after cleaning and phosphating. There are two characteristics of a good primer: adhesion and corrosion resistance. Adhesion means that the primer binds to bare metal and then binds to whatever paint will be applied over it. The primer must create a tight bond between the bare metal and subsequent paint layers. Wetting is the term used to describe the bond between a bare substrate and liquid primer. Good wetting characteristics means that a liquid paint can attach to a substrate by surface attraction. The crystals of zinc phosphate on treated bare steel give it good wetting characteristics. Chemicals inside the primer, such as epoxy resin, give the primer good wetting characteristics.

Primer is the first line of defense in the fight against corrosion. Therefore, moisture must not be able to penetrate through a primer to reach the underlying steel. Corrosion resistance also means that the primer creates such a tight bond to the metal that rust cannot creep under it.

The corrosion resistance of a primer can be tested in the following manner. A bare metal test panel is sprayed with the primer. After curing, the primer is scratched to expose bare metal to the air. The panel is then sprayed with a 5% salt-water solution for as long as two weeks. Under these conditions, the bare metal in the scratch will quickly rust. A poor primer will allow rust to spread from the scratch to the surrounding metal. The bond between a good primer and underlying metal is so strong that it will prevent the spread of rust.

In the past, nitrocellulose and acrylic lacquer primers were used. Avoid these outdated types of primers. These lacquer-based products are not durable and can cause problems when used with enamel topcoats.

Self-etching Primer

A ***self-etching primer*** combines cleaning, phosphating, and priming into one procedure. The self-etching primer will neutralize microscopic rust and adhere to the bare metal to prevent corrosion. See **Figure 25-19**. This type of primer is a two-component product. One component is a vinyl base and the other is phosphoric acid. The acid will gradually evaporate, so pot life is dependent on how long the phosphoric acid stays in the paint after the two components are mixed. Check the manufacturer's recommendations on pot life for the specific product being used.

Do not store already mixed self-etching primer in a metal can. The self-etching primer will react with the can and lose potency. Even though manufacturers state that self-etching primer can be mixed and stored for as long as seven days, it is best to spray self-etching primer as soon as it is mixed. Self-etching primer is not meant to be sanded. A surfacer, which is designed to fill imperfections, is usually applied over the self-etching primer after the primer has flashed. Self-etching primer may be used on bare aluminum.

A ***wash primer*** is a special type of self-etching primer. Self-etching primer has a vinyl base that makes it thick, but a wash primer does not have a vinyl base. The wash primer is thin and transparent. Some paint manufacturers call wash primer a pre-coat primer.

Epoxy Primer

An epoxy primer is a two- or three-component primer. The epoxy primer is mixed with an activator, and in some brands, a reducer. The mixture will have a pot life. Epoxy primer does not treat bare metal. If rust is visible in the bare steel, the steel should be cleaned with acid and treated with a conversion coat. Some manufacturers contend that, if the repair area has been exposed to air for only a brief time period, less than one hour, epoxy primer may be applied over the bare metal without treatment.

Some brands of epoxy primer have an ***induction period***. An induction period is the time after mixing when the components in the paint are still interacting. An epoxy primer cannot be sprayed until the induction period has ended.

Epoxy primer adheres well to bare metal and prevents rust from forming. See **Figure 25-20**. Also, epoxy primer is not meant to be sanded. A surfacer can be applied directly over the epoxy primer after flash time. ***Flash time*** is the number of minutes that must elapse between coats of paint. Flash time allows solvent to evaporate from the newly applied coat of paint. The surface is no longer wet, but remains tacky enough to keep the second coat from running. Enough solvent remains to help bond the first coat to the second, but not enough solvent to cause solvent pop.

Surfacer

Surfacer is designed to fill imperfections. Surfacer is applied to build up low spots inside featheredged areas, **Figure 25-21**. Once the surfacer has dried,

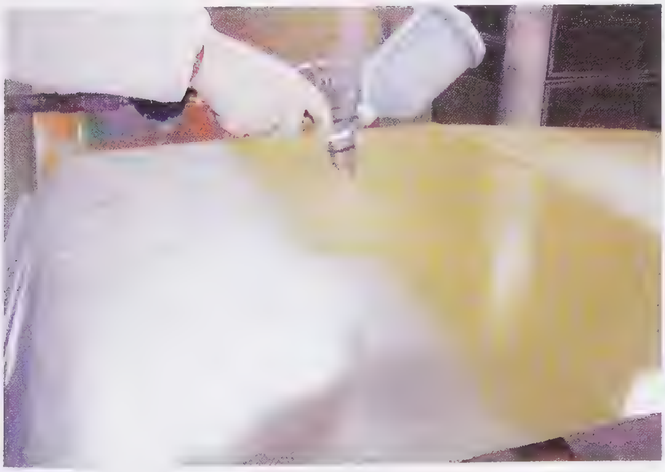


Figure 25-19. *Self-etching primer binds to the bare metal.*

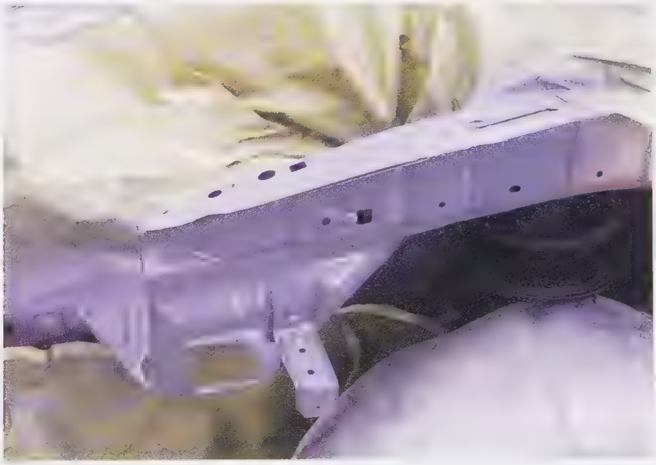


Figure 25-20. *Epoxy primer has been applied to the bare metal on this upper rail and apron.*

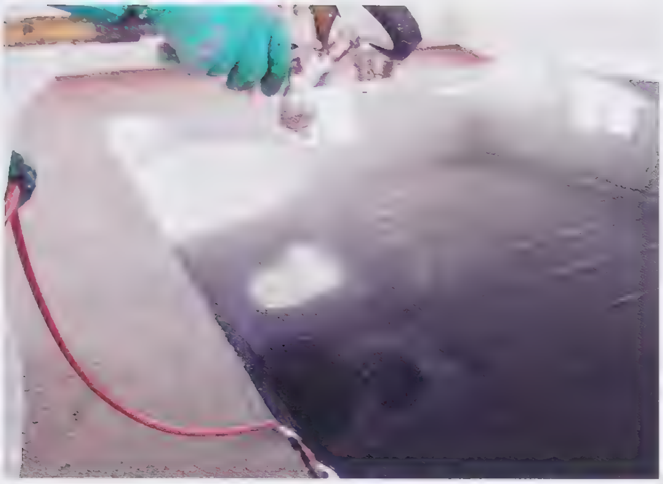


Figure 25-21. *Surfacer is applied within the sanded areas to fill a featheredged area.*

it is block sanded. There are several types of surfacers available: nitrocellulose lacquer, acrylic lacquer, synthetic enamel, urethane, and polyester.

When topcoat paint is applied over any paint, including surfacer, the solvents in the topcoat will soak into the layer of paint below. ***Hold out*** is the ability of the surfacer to resist absorption of the topcoat. Solvent soaking into surfacer can cause two problems. Scratches that were filled with surfacer and block sanded out may reappear because the topcoat solvent softens and swells the surfacer in the scratch. When the topcoat solvent evaporates, the surfacer, which now has a slightly smaller surface area, sinks back into the scratch, taking topcoat down with it. The surfacer, even with the addition of topcoat, no longer entirely fills the scratch. The second problem is that a topcoat that soaks into the surface may have a dull appearance. A good surfacer is able to resist the adverse effects of the topcoat solvent. Also, the undercoat may contain a pigment, such as chromate, that may be visible in a light-colored topcoat. The appearance of an undercoat pigment in the topcoat is called ***bleeding***. A quality sealer is the best way to eliminate bleeding.

A positive characteristic of a good, scratch-filling surfacer is build. ***Build*** is the thickness of paint film, measured in mils. A mil is 1/1000 of an inch. Manufacturers add talc to surfacer to enhance build. A high build primer, for example, can leave a paint film that is 2.5–3 mils thick.

Bridging, a characteristic of build, can also cause sanding scratches to appear in the topcoat. ***Bridging*** occurs when improperly mixed surfacer is too thick to flow into and completely fill the scratch. The topcoat then sinks into the scratches making them visible. Under-reduced surfacer or a surface diluted with a reducer that evaporates too quickly are the most probable causes of bridging.

For a surfacer to properly fill scratches, it must flow into and fill the scratches. However, the scratches cannot be too wide or too deep. Usually, 180-grit scratches are narrow and shallow enough to be properly filled by surfacer. Any scratches from 80-grit or coarser sandpaper may cause a problem.

When topcoat is sprayed over the surfacer, the surfacer must not ***shrink***. Therefore, it is best to avoid lacquer-based surfacers. Lacquer will soften when exposed to strong solvent. The reducer in a topcoat may be strong enough to affect a lacquer surfacer and cause it to shrink. Surfacer shrinkage will show up as scratches or ruts in the topcoat. Urethane or polyester surfacer is a better choice. Urethane surfacer is usually a three-component paint that consists of a surfacer, a hardener, and a reducer. The components are mixed together in the proportions specified by the manufacturer. The use of a hardener means that this type of surfacer will contain isocyanates and have a pot life. Urethane surfacer adheres well to self-etching and epoxy primers. Usually two to three coats will provide enough build to fill 180-grit scratches.

The remaining characteristics of a good surfacer are ease of sanding and quick curing. Ease of sanding means that the surfacer will sand dry without loading the sandpaper with bits of uncured resin. Quick curing means that the surfacer will crosslink, or dry, in a minimal amount of time. Sanding and painting a surfacer before it has completely cured will result in shrinkage and scratches in the basecoat. A quality surfacer can air cure in 2 hours or infrared cure in less than 30 minutes.

Cure time depends on shop temperature, airflow, and the number of coats applied. At 70°F (21°C), the surfacer may cure in approximately 2–3 hours. Once the surfacer has cured, it should be block sanded to prepare for the topcoat. Some brands of surfacer can be tinted to match the topcoat color. This allows the topcoat to hide the surfacer with fewer coats, saving time and topcoat cost.

Sealer

A ***sealer*** acts as an adhesion promoter, helps achieve a uniform topcoat color, forms a barrier over sensitive substrates, and provides hold out.

Sealer functions as an adhesion promoter when an entire vehicle is refinished. The existing topcoat is sanded with 400-grit paper and the entire vehicle is sprayed with a sealer. The sealer bites into the sanded paint. The topcoat then bonds with the sealer.

A uniform color is important when spraying a poor-hiding topcoat. The sealer can be tinted or mixed to help the topcoat cover in a minimum amount of coats. **Figure 25-22** shows a situation where uniform color is needed. If a vehicle is to be refinished in the same color, a clear sealer will show the original color and enhance hiding.

Sealers can be used to form a barrier over sensitive substrates. For example, solvent in the topcoat can react with underlying thermoplastic paint. To prevent this undesirable reaction, a barrier coat can be applied over the sensitive substrate. The solvents in the topcoat cannot penetrate the barrier coat, so no adverse chemical interaction can take place. Waterborne sealer is used over sensitive substrates.

Holdout is a desirable quality in a sealer. A urethane surfacer will provide sufficient holdout, eliminating the need for a sealer. Epoxy primer can also be used as a sealer.

There are several sealers available. Dedicated sealers are usually either tintable or mixed to produce shades of gray. This allows the sealers to be easily hidden by the topcoat. Sealers are sprayed immediately before the topcoat. There is no sanding of the sealer in this wet-on-wet application. Therefore, it must be applied smooth for the topcoat to look good.

As an adhesion promoter, a sealer can be sprayed over sanded ***E-coat*** on new replacement parts. E-coat, which is an electrode deposition primer, is applied to a bare metal part at the factory. The sealer will bite into the sanded E-coat and the topcoat will bond with the sealer. See **Figure 25-23**. Some brands of sealer are designed for spraying over unsanded E-coat. Sanding is not necessary if the replacement part is not normally exposed to the ultraviolet radiation in sunlight. An example would be the underside of a hood. The underside of the hood is cleaned and the sealer is sprayed on. No scuffing is required, so there is a big savings in labor.

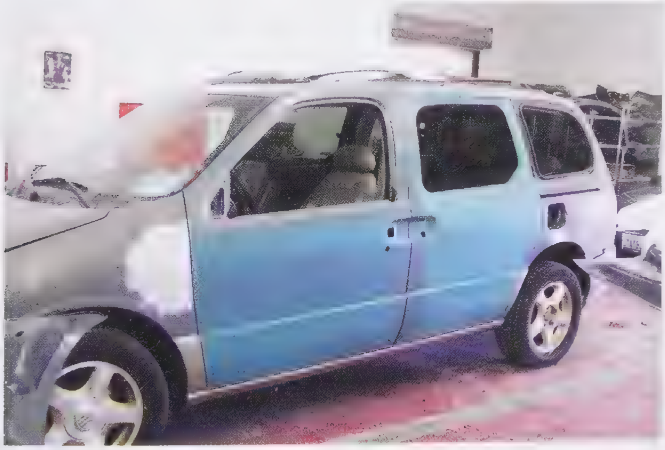


Figure 25-22. *This vehicle has had two used doors installed. The paint on the used doors has been scuffed. The application of a sealer will make them a uniform color.*

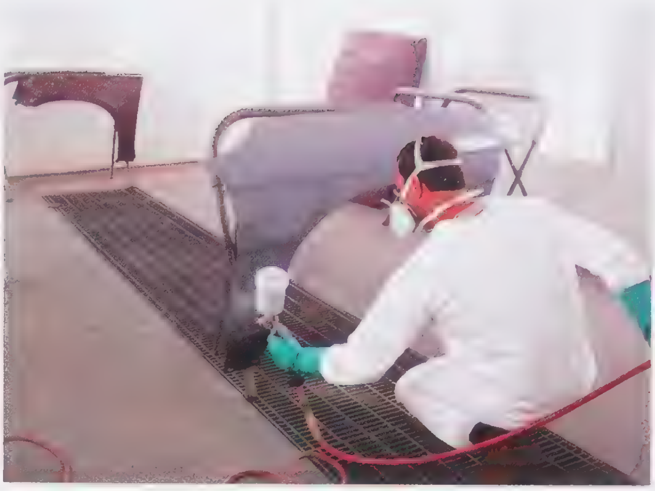


Figure 25-23. *Sealer is applied over scuffed E-coat. The basecoat will adhere to the sealer.*

Dual-Use Undercoats

An undercoat that combines two functions is known as a ***dual-use undercoat.*** An example of a dual-use undercoat is primer-surfacer. A primer-surfacer binds and fills. Some primer-surfacers can be applied to bare metal, but the metal must first be acid etch/conversion coat treated. At least one primer-surfacer is available that functions as a self-etching primer and a surfacer. This product can be mixed two ways. In the first mixing ratio, the undercoat is a self-etching primer. In the second option, the ratio contains one-half the amount of reducer. The resulting undercoat is thick enough to fill scratches. Another example of dual-use is a primer-sealer. Epoxy primer is a primer-sealer. It is able to adhere to bare metal or existing paint.

Rock Guard

Rock guard can be sprayed and dries to a thick, chip-resistant coating. Many vehicles have rock guard installed at the factory. See **Figure 25-24**. It can be found on rocker panels and other lower body parts, and looks like heavy orange peel. Rock guard is applied just before the topcoat, after surface preparation is complete. If a definite edge is needed, masking tape and paper can be used. If a tapered edge is needed, no masking is required. Rock guard is packaged in aerosol cans. Apply two or three coats with sufficient flash time in between coats. Once the rock guard has cured, it can be topcoated. Do not apply rock guard over bare metal or on top of a topcoat.

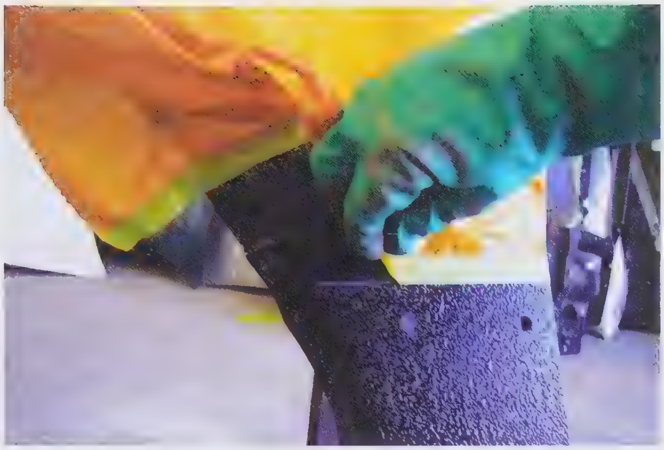


Figure 25-24. *Rock guard has been sprayed on this fender. Notice the hard line left by the masking tape.*

Adhesion Promoter

Adhesion describes paint's ability to bond to a surface or an existing paint. Paint that is properly adhered will not flake off after curing. An ***adhesion promoter*** acts as a glue to hold refinish paint to existing paint.

Clearcoat is a hard, impervious layer of paint. Much of the refinishing in a modern body shop requires that existing clearcoat be scuffed and sprayed with refinish clearcoat. When an adhesion promoter is sprayed onto a scuffed, existing clearcoat, it does two things: it chemically bonds with the existing clearcoat and it mechanically bonds with the scratches and scuffs. When the refinish clearcoat is sprayed over the adhesion promoter, the clearcoat and the adhesion promoter will chemically bond.

Adhesion promoter also fills and levels the scratches made when scuffing the existing clearcoat. This ability to fill scratches is especially important when spraying metallic basecoats. If a metallic basecoat were applied over an irregular surface, the metallic flakes will not be uniformly oriented. Uniform orientation means the metallic flakes are laying flat and all of them are reflecting light in the same way. On an irregular surface, some of the metallic flakes may be tipped and not lay flat. This irregular flake positioning would cause them to reflect light differently than all the other flakes that are laying flat. This difference in light reflection would show up as a slightly different, usually lighter, variation in the basecoat color.

Adhesion promoter is ready-to-spray. It does not need reduction or catalyzing. It is also colorless and thin, so runs may be a problem. This is important to know because adhesion promoter is not to be sanded before refinish clearcoat application. Therefore, the adhesion promoter must be sprayed smooth for subsequent coats to go on smooth.

Abrasives

Abrasives are used in surface preparation before and after paint application. There are many types of abrasives. One way to classify abrasives is by how aggressive they are. At one extreme are the aggressive abrasives that can remove metal, and at the other extreme are abrasives so mild they barely remove the gloss from paint.

Sandpaper

Sandpaper is used for surface preparation before painting; afterward it is used to prepare painted surfaces for final buffing and polishing. The abrasive particles on the surface of sandpaper are called grit. Grit size refers to the size of the particles of abrading materials embedded in the sandpaper. Grit size is indicated by a number printed on the back of the sandpaper. A low number indicates that the paper is coarse, while a higher number means the paper is less coarse. Therefore, 24-grit sandpaper is coarser than a 220-grit paper.

When choosing sandpaper, match the grit to the job. Always choose the finest grit of sandpaper that will quickly do the job. For example, if you need to remove OEM paint, you could use a 24-grit, 80-grit, or even 600-grit sandpaper. The 24-grit sandpaper is so aggressive that it will cut deep scratches in the underlying metal as the paint is removed. Deep scratches are difficult to remove, requiring extra time, effort, and materials. The 80-grit sandpaper also will remove the paint. It will be a bit slower than the 24-grit disk, but the metal will not be deeply scratched. On the other hand, stripping OEM paint by sanding with 600-grit sandpaper would certainly not gouge the metal, but the job would take forever. To quickly remove paint, 600-grit sandpaper is a poor choice for the job.

Sandpaper is abrasive bonded to a backing material. Some backing material is rated by stiffness. The letters A through E indicate progressively thicker, more inflexible backing. The letter E indicates a relatively thick, rigid backing material. The letter A corresponds to the thinnest, most flexible backing.

Open-coat sandpaper has more space between the grit particles when compared to a ***closed-coat*** sandpaper. Open-coat sandpaper can hold a small amount of sanding debris in these open spaces and not clog readily. Clogged sandpaper, which has sanding debris covering the abrasive grit, cannot cut and is useless. The larger the grit, the more space between grit particles. Abrasive particles completely cover the surface of closed-coat sandpaper.

There are four separate systems used to rate the size of the abrasives on sandpaper. Because of these different systems, two sandpapers with the same grit number (from different manufacturers using different systems) may not produce the same size scratch. For dry sandpaper grits from 16–80, the Coated Abrasive Manufacturer's Institute (CAMI) system is used by many manufacturers. Wet or dry sandpapers, up to 220-grit, use the CAMI system.

During manufacture, the abrasive particles are sorted by size. The abrasive, aluminum oxide or silicon carbide, is poured through a series of progressively smaller mesh sizing screens. This method allows abrasive of incorrect size to be placed on the sandpaper. For example 40-grit sandpaper may contain abrasives of 36-grit size as well as 80-grit size. These lower grit number sandpapers will not be used for finish sanding so a close tolerance is not required. With higher grit numbers, because they will be used for finish sanding, a more efficient means of abrasive sorting is utilized. The Federation of European Producers Association (FEPA) sorts abrasives to a higher tolerance than CAMI; resulting in sandpaper with less variation in the abrasive particle size. FEPA-rated sandpaper grit is preceded by the letter P. Usually the FEPA-rated sandpaper, dry/wet or dry, ranges from P80 to P800. Grits finer than 800 often rely on the Japanese Industrial Standard (JIS) system. JIS-rated sandpaper has no letter prefix. The CAMI, FEPA and JIS systems of grit numbers are not necessarily equivalent and may be greatly different. Micron-rated sandpaper is manufactured to the highest tolerance. Micron-rated sandpaper, which has more uniform abrasive size than the other systems, does not use grit number; instead the size of the abrasive, 5–100 microns, is listed. The smaller the micron number, the finer the scratch.

Sandpaper can be classified as dry, wet/dry, or damp. Dry sandpaper will disintegrate if it becomes wet. Dry sandpaper, used on a sander or by hand, is used to sand body filler, strip paint, block sand, and color sand cured paint. Wet/dry sandpaper does not have as wide a range of grits as dry sandpaper. Wet sandpaper is waterproof and is designed to be soaked in water before use. Water acts as a lubricant and permits faster cutting with less clogging. There are some tasks in which the water in wet sanding would create a problem, such as sanding body filler.

Many sanding tasks could be accomplished by either dry or wet sanding. Some examples would be sanding clearcoat or a sanding new replacement part. In general, dry sand anything that has bare metal or bare body filler or that will make metal bare, such as stripping. While dry sanding produces dust, wet sanding makes sludge. The technician can decide whether to use dry sanding or wet sanding for other tasks.

Damp sanding uses an abrasive-coated foam pad. The cutting surface of the pad is sprayed with water, so the pad is damp, but not soaking wet, while sanding. A spray bottle is used to apply water to the disk. The disks do not feel gritty or rough; they have an even, flat surface. The damp sand pad is conformable enough to sand slightly irregular surfaces. The foam pads are available in grits ranging from 800 to 3000. The foam pads can be used to scuff clearcoat for a blend and to color sand prior to buffing.

Wet sandpaper can be attached to the sanding pad with a water-insoluble adhesive, but more commonly the sandpaper is simply wrapped around the sanding pad and held in place by friction. Some sanding blocks have teeth to pierce the sandpaper and hold it in place.

Dry sandpaper can be purchased with a Velcro-type backing, a sticky adhesive backing, or plain with no backing. See **Figure 25-25**. The backing attaches the dry sandpaper to the sanding tool. The Velcro-backed and adhesive-backed sandpapers require a special pad. An adhesive-backed paper is shown in **Figure 25-26**.

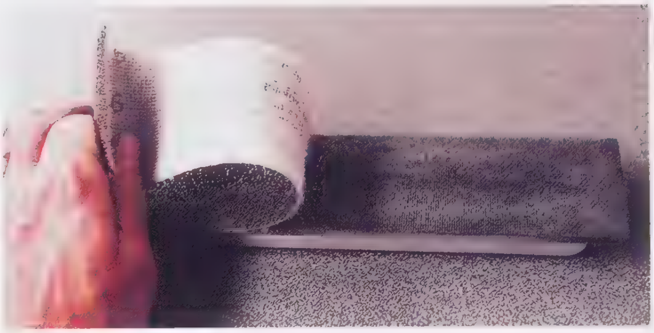


Figure 25-25. *This sandpaper is attached with a Velcro-type backing. The sandpaper can be removed and reinstalled many times.*

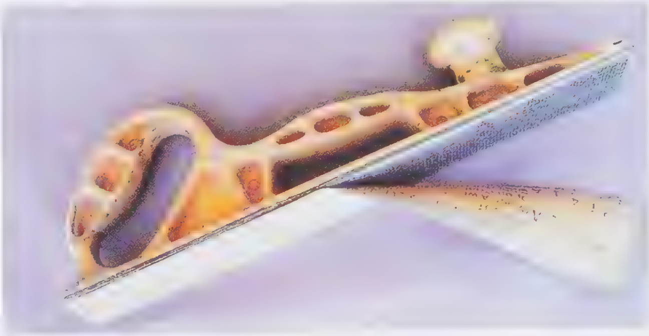


Figure 25-26. *This sandpaper has an adhesive backing. The sandpaper can be installed and removed but not reinstalled. Reinstalled sandpaper will not stick.*

This type of paper is attached to a clean foam surface on the sanding tool. The disadvantage of adhesive-backed paper is that once it has been installed and removed, it cannot be reused. Some sanding tools have clips or fasteners that hold the paper in place.

Long board sandpaper is 2 3/4" wide. Precut long board sheets are available. These are 17 1/2" long. Also, for some grits of paper, the paper is available on a roll as shown in **Figure 25-27**. The paper can be cut to length as needed.

Jitterbug sandpaper is 3 3/4" wide. The sandpaper is usually precut into 9" long strips. Jitterbug sandpaper is the width and a little longer than the length of the pad on a jitterbug. The extra length allows the paper to wrap around the pad and fit into the retaining clips.

For wet sanding prior to painting, wet/dry sandpaper is used. The paper should be softened by soaking it in water for at least ten minutes before use. Wet/dry sandpaper is usually available as 9" × 11" sheets. The sheets can be torn as shown in **Figure 25-28** for use on a sanding block or pad. The common grits of sandpaper used in the collision repair shop are identified in **Figure 25-29**.

After paint is applied, sandpaper is used to prepare the painted surface for buffing. Dry sandpaper may be used on a dual-action sander. The commonly used grits are 1200 and 1500. Sandpaper for a dual-action sander is 6" in diameter.

Wet sandpaper is used to remove orange peel, runs, and dirt. Coarser sandpaper cuts faster, but leaves deeper scratches. Always choose the least aggressive method.

Specialized sandpaper can be used in a special holder as shown in **Figure 25-30**. This holder limits the sanding to a small area and is ideal for removing isolated specks of dirt.

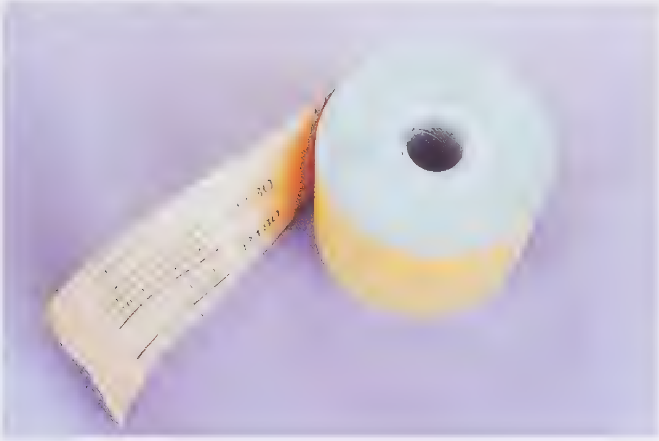


Figure 25-27. *This adhesive sandpaper is cut to whatever length is needed.*

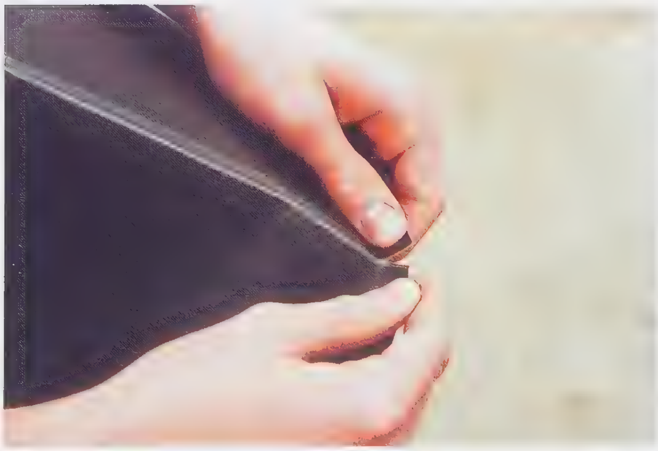


Figure 25-28. *Crease the sandpaper before tearing it.*

Match Sandpaper to the Application

Type of Sandpaper	Grit	Application
Dry	24	Paint stripping
Dry	36	Paint stripping
Dry	80, 180, 320	Featheredging (use in sequence shown)
Wet/Dry	600	Final sanding of surfacer
Dry	800	Dry sanding for clearcoat blend
Wet/Dry	1000	Wet sanding for clearcoat blend
Wet/Dry	1200	Removing heavy orange peel and runs from painted surfaces
Wet/Dry	1500	Removing dirt from painted surfaces
Wet/Dry	2000	Removing light orange peel from painted surfaces

Figure 25-29. *Selecting the wrong sandpaper for the task creates additional work.*

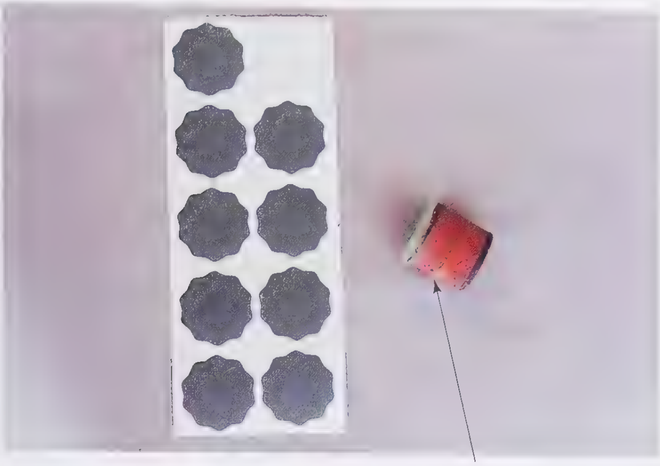


Figure 25-30. *This special holder sands a very small area. This is necessary when sanding out a dirt speck in the clearcoat prior to buffing.*

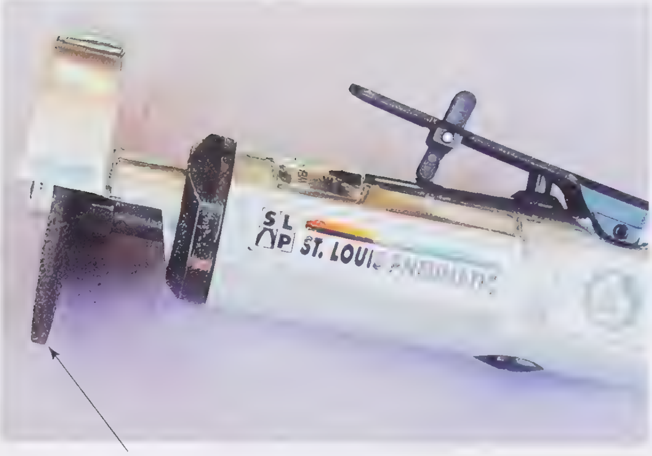


Figure 25-31. *This cutoff wheel is used to grind welds.*

Blasting Material

Choice of blasting media should be determined by the type of job. As with sandpaper, use the least aggressive blasting material that will get the job done quickly. For example, rust removal calls for an aggressive blasting media such as silicon carbide or aluminum oxide. They will effectively remove both paint and rust, but they will pit the metal with many tiny gouges. A plastic or poly abrasive is less aggressive than the silicon carbide or aluminum oxide. The plastic media will remove paint from a non-rusty panel with minimal damage to the underlying metal. Powder can remove a single layer of paint, leaving the paint underneath intact.

In a system that reuses the media, such as a cabinet sand blaster, the blasting media will eventually wear out. In time, the abrasive is pulverized into a dull powder that's incapable of removing paint or rust. Change the media to ensure that it functions effectively.

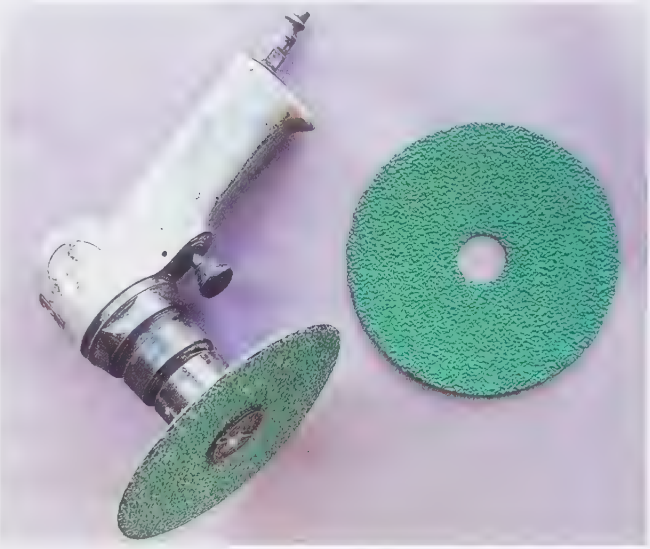


Figure 25-32. *The grinding disk is mounted on the air grinder.*

Cutoff Wheel

A ***cutoff wheel*** is the most aggressive tool used in pre-paint preparation. Be careful not to overuse this tool as it will create deep gouges in the metal, which will require additional time and effort to remove.

Before painting a welded area, the excess weld metal must be removed. A thick cutoff wheel will quickly grind down a weld. **Figure 25-31** shows an air-powered cutoff wheel.

Grinding Disk

A ***grinding disk***, shown in **Figure 25-32**, is available in 50-, 36-, and 24-grit varieties. A grinding disk can quickly remove paint, as well as metal. Any grinding disk can easily put deep scratches into a metal surface. These scratches will be difficult to remove by sanding, so the typical procedure is to fill the scratches with body filler. If a MIG weld is ground down with a cutoff wheel, use a 24-grit grinding disk on a grinder to remove the remains of the MIG weld that the cutoff wheel could not reach. Plan on filling the 24-grit scratches with body filler.

Grinding disks are available in 7", 5", 3" and 2" diameters. The smaller diameters are useful for grinding in confined areas, such as inside a wheel well. The large disks are attached to the grinder with a flat nut as shown in **Figure 25-33**. The smaller disks, **Figure 25-34,** are mounted in a holder and powered by a drill or grinder.

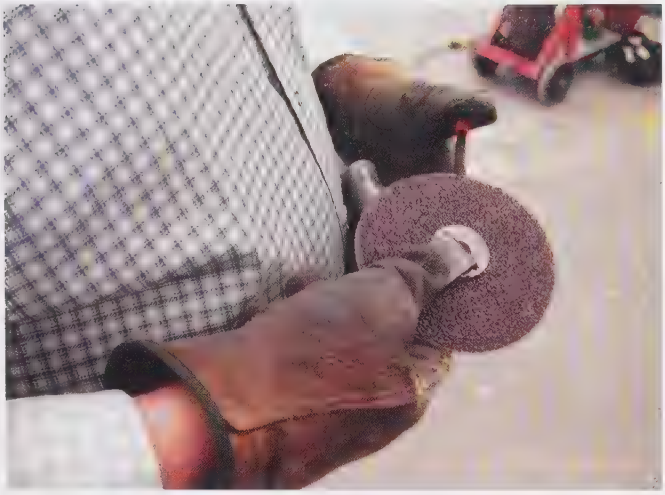


Figure 25-33. *The grinder disk is removed with special tools to hold the flat nut stationary and to turn the air grinder shaft.*

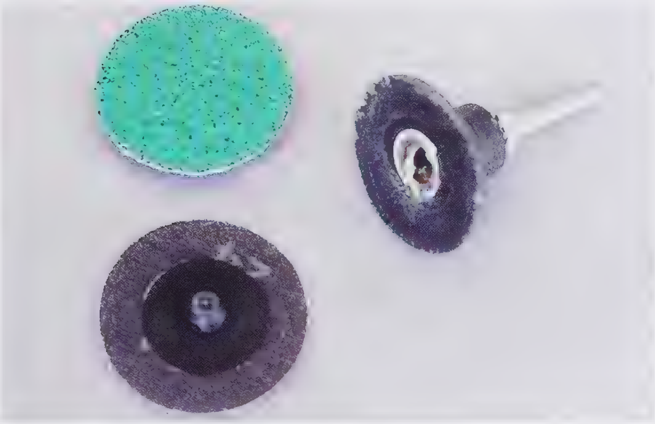


Figure 25-34. *These small grinder disks screw into a special holder. The holder can be powered by an electric drill or an air-powered angle grinder.*

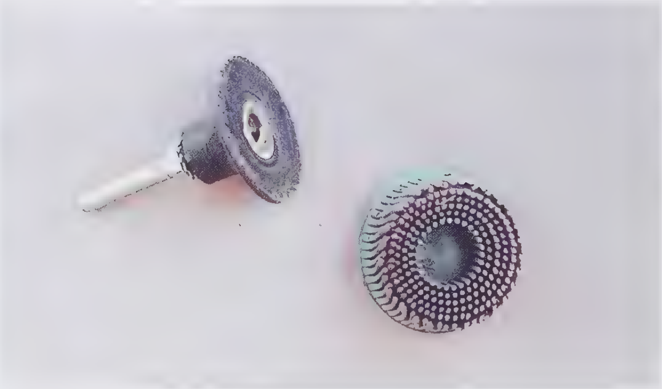


Figure 25-35. *This plastic abrasive disk removes paint but does not remove metal.*

Abrasive Disks

Abrasive disks remove paint but not metal. One style of abrasive disk is shown in **Figure 25-35**. These disks are color coded. The white disk is coarse, the yellow disk is medium, and the green disk is fine.

Abrasive disks are for stripping. They should not be used for partial removal of paint, as paint tends to melt and smear as it is stripped with the disk. Irregular surfaces, such as weld areas or the convolutions on a valve cover, are easily stripped with abrasive disks. The abrasive disk will gradually be worn down with use. A special holder is used to connect the abrasive disk to an electric or air-powered drill. A small air-powered angle grinder can also power the abrasive disk.

A ***plastic wheel*** is similar to an abrasive disk in that the metal is not damaged during paint removal. However, the plastic wheel is made of a different material. These tools are small, so it is generally not efficient to strip areas larger than one square foot with a plastic wheel.

For larger areas, such as an entire panel, use a ***stripping pad***. A stripping pad will do minimal damage to metal while removing paint. The abrasive pad is a 6" diameter disk that is attached to a Velcro-type holder. The holder and disk are attached to a grinder/buffer. The stripping pad will clog with paint and wear down along the edges with use. The stripping pad will leave a few scratches in the bare metal, but these scratches can be removed by sanding with 80-grit sandpaper.

Too much heat can easily warp a thin metal panel, and the friction between a stripping pad and metal surface can generate enough heat to warp metal. To minimize heat buildup, do not grind or sand on one area for too long. Keep the tool moving around the panel. Do not dwell on the same spot for more than a few seconds.

Abrasive Pads

Abrasive pads, or scuff pads, are used to scuff paint. The color of the pad indicates its level of abrasiveness. A red pad is coarse, similar to 600-grit sandpaper; gray is fine, similar to 1000-grit sandpaper; and gold is very fine, similar to 2000-grit sandpaper. Scuff pads may be used dry and are typically hand-held. However, if too much pressure is applied, the scuff pad will leave finger marks as shown in **Figure 25-36**. Avoid finger marks by maintaining a light pressure on the pad. An abrasive pad can also be attached to a Velcro-backed disk or pad for use on a power sander.

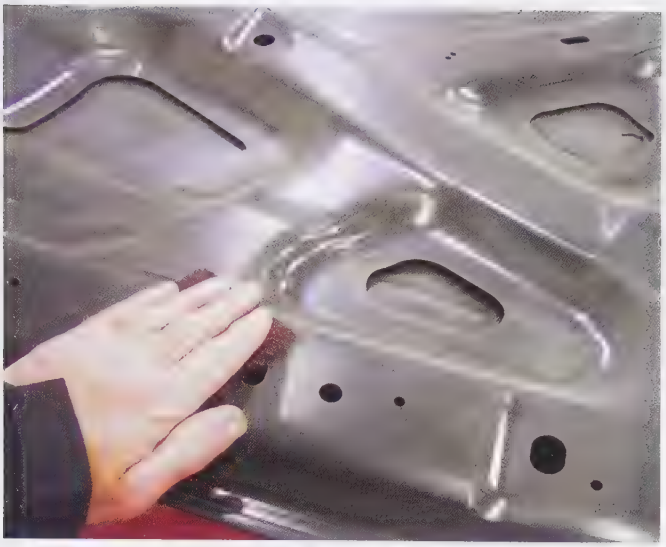


Figure 25-36. *A scuff pad conforms to the shape of a panel. Do not press down too hard.*

Sanding Paste

Sanding paste is a mild abrasive cleaner. It is used to scuff clearcoat before blending. A wet, gray (1000-grit) scuff pad is used to work the paste into the clearcoat. The abrasive in the paste scours the paint, cleaning and gently abrading. Sanding paste being applied with a scuff pad is shown in **Figure 25-37**.

Chemical Paint Removal

Chemical paint stripping is a fast and easy way to remove automotive finishes down to bare metal. It is dust free, unlike mechanical paint stripping techniques, but chemical paint removal comes with its own set of dangers. Always use chemical resistant gloves, avoid getting stripper on your skin or in your eyes. Ventilation with fresh air is important during chemical paint stripping. Upon completion, dispose of residue according to the manufacturer's instructions.

Paint Stripper

Paint stripper is a thick gel-like liquid that attacks and dissolves the paint's binder, loosening the bond between paint and substrate. **Figure 25-38** shows paint stripper in use. Paint stripper will cause the paint to bubble and lift up and away from the metal surface. The bubbled paint should be scrapped off in a way to minimize damage to the underlying substrate. Once the paint stripper is removed, small amounts of stripper residue remaining on the surface must be neutralized with water.

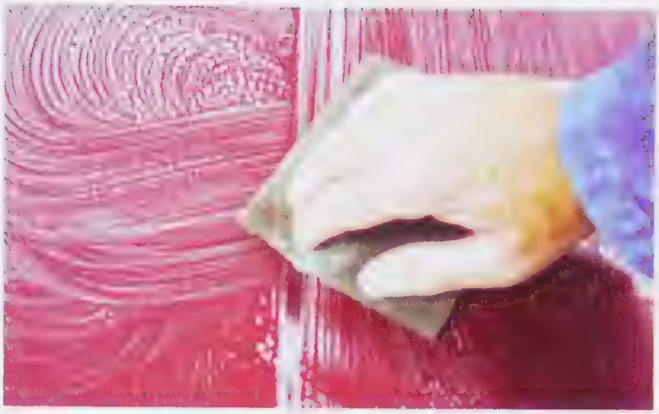


Figure 25-37. *Sanding paste is used with a scuff pad to prep existing clearcoat for the application of clearcoat. The scuff pad is soaked in water. The sanding paste is a thick liquid. Scuffing action makes suds.*

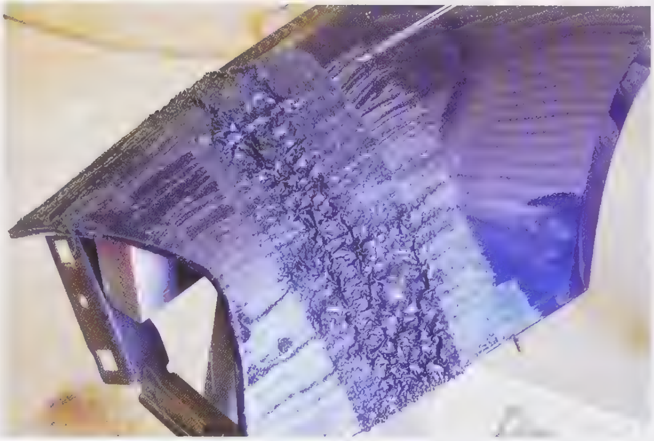


Figure 25-38. *Paint stripper has been applied to this fender. Notice that the paint is blistering and bubbling.*

Paint strippers for metal and plastic are available, but they are not interchangeable. A paint stripper for metal parts should never be used on plastic parts as it will harm the plastic.

Cleaners

Two types of contaminants may be on a vehicle's painted surface: water soluble and solvent soluble. Soluble means a liquid is able to dissolve a solid substance. Solubility is dependent on polarity. A polar substance, like water, will dissolve another polar substance like salt.

A nonpolar substance, like oil, can only be dissolved by another nonpolar substance, like wax and grease remover. Oil and water do not mix because one is polar and the other is nonpolar. Water cannot dissolve oil.

First, remove water-soluble contaminants, such as road salt, mud, tree sap and bird droppings, with soap and warm water. Wet the area to be cleaned with water and use a sponge and soapy water to wipe the panels clean. Rinse off the soap and dry the panel with clean towels.

The surface of a vehicle may be covered with invisible contaminants. A solvent is used to remove oil-soluble contaminants, such as wax, grease, and tar. ***Pre-sanding solvent*** evaporates slowly and may penetrate the surface because it stays wet. This type of solvent is considered aggressive and will dissolve heavy tar contamination, **Figure 25-39**. ***Pre-paint solvent*** evaporates quickly. It will not penetrate the surface because it dries quickly. However, it will not remove heavy contamination, **Figure 25-40**.

A pre-sanding solvent is used to clean the vehicle after washing with soap and water. If the pre-sanding solvent were used immediately before painting, the solvent in the paint may cause sand scratch swelling. Using a pre-paint solvent, which evaporates rapidly, does not cause sand scratch swelling because the solvent rapidly evaporates and does not have time to soak into the surfacer.

Waterborne solvent is specially formulated to reduce VOCs produced when cleaning oil-based contaminants. Waterborne solvent contains water and special water-soluble solvents that are capable of dissolving oil. Waterborne solvent evaporates quickly. It is a low-VOC solvent and, therefore, will not remove heavy contamination.

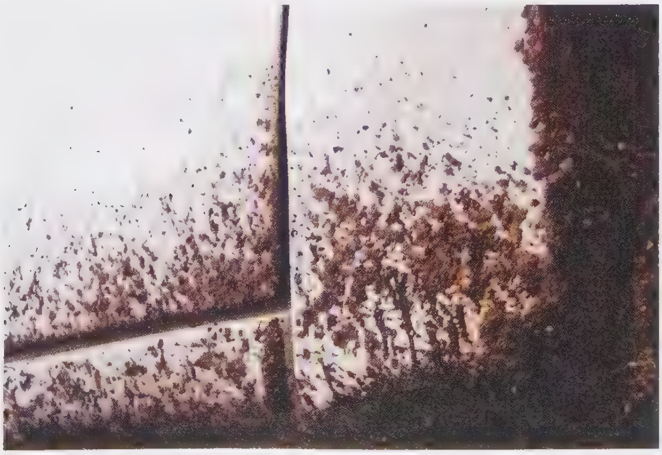


Figure 25-39. *This extremely heavy road tar contamination should be sprayed with pre-sanding solvent to soften the tar.*

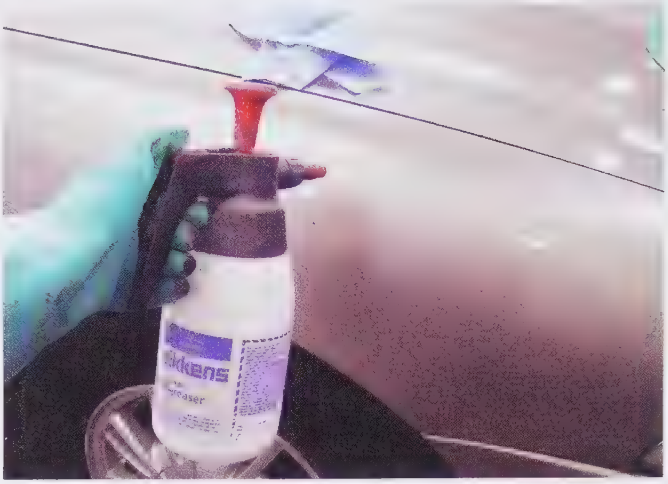


Figure 25-40. *Pre-paint solvent will dissolve light contamination such as fingerprints.*

Tack Rag

A ***tack rag*** is a loosely woven fabric coated with a sticky resin. When gently wiped over a surface before painting, a tack rag will pick up and hold any dust and dirt specks. See **Figure 25-41**. The tack rag should be unfolded completely and lightly wadded into a fluffy pad before use. The resin on the tack rag will leave no residue that may interfere with painting. With use, a tack rag will load up with dust and lose the ability to pick up and hold contaminants.

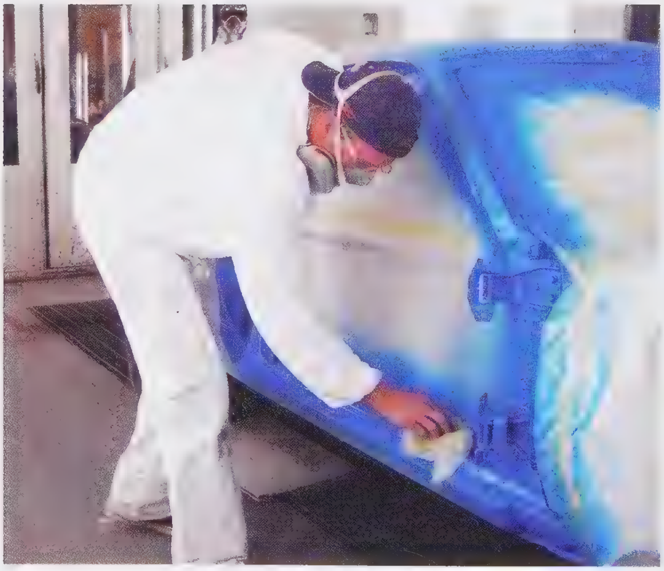


Figure 25-41. *This paint technician is using a tack rag to remove contaminants before applying another coat of basecoat to this classic car.*

Seam Sealer

Seam sealer prevents the entry of water or exhaust gases into a vehicle. It also keeps rust-causing mud from collecting in the gaps between panels.

There are two types of tube-applied seam sealer and another kind that is applied with a brush. Single-part seam sealer is applied with a caulk gun. This seam sealer has a cure time that must elapse before it can be painted. The single-part seam sealer cures by solvent evaporation. An air-powered caulk gun applies a continuous and uniform bead, not the inconsistent bead application typical of a hand-powered caulk gun. The gun can be adjusted to apply a bead or a wide, thin coat of seam sealer as shown in **Figure 25-42**.

Two-part seam sealer utilizes a special delivery system that keeps the two components, a sealer and a hardener, separated until needed. The sealer and hardener combine as a plunger pushes them through a mixing tube. Two-part seam sealer cures faster than single-part seam sealer, with a better finish. Some two-part seam sealers are self-leveling. Self-leveling means that prior to cure, the seal sealer will flow enough to make a smooth bead surface.

Brushable seam sealer is scooped out of a can and spread with a brush. This application method duplicates the OEM seam sealer in the trunk floor. See **Figure 25-43**. The brushable seam sealer is a single-part sealer. An improperly sealed can will harden solid.

Masking Materials

Masking materials are used to protect the vehicle when priming or painting. Masking materials must protect the covered surface from paint and attach securely enough so as not to be blown off by the spray gun, booth fan, or blow gun.

Masking Paper

Masking paper is available in 3", 6", 12", 18", and 36" widths. Some masking papers are coated. Coated papers are usually waterproof. A coated paper is also less likely to shed paint-contaminating fibers. Waterproof paper is not damaged by water from wet sanding. Waterproof masking paper can also be soaked in water to make it more conformable. For example, wet masking paper can be wrapped around a tire for a tight fit. Masking paper is available in different thickness, or weights. The color of the paper often indicates the weight. See **Figure 25-44**.

Masking Tape

Standard ***masking tape*** is available in 3/4", 1", 1 1/2", and 2" widths. This type of masking tape is used to hold masking paper in place, as well as to block paint.

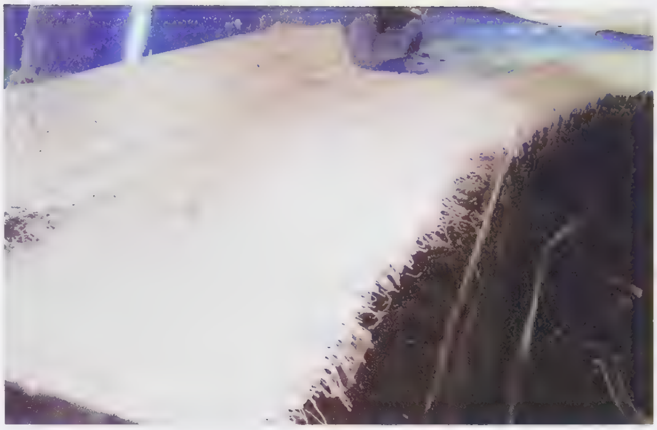


Figure 25-42. *This wide, thin coat of seam sealer was applied to the inside joint of a trunk floor after trunk floor replacement.*

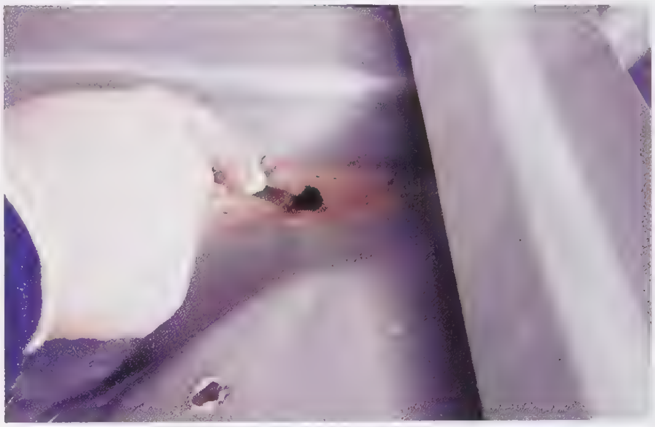


Figure 25-43. *Brushable seam sealer keeps noxious fumes out of the vehicle. It also prevents water and mud from lodging between panels.*

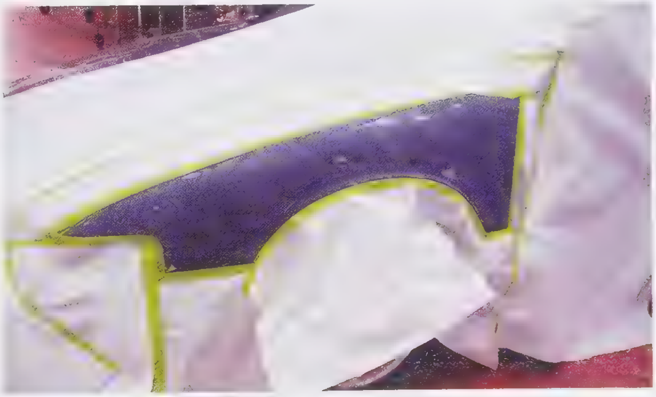


Figure 25-44. *To paint this fender, the rest of the vehicle must be protected with masking tape and masking paper.*

Plastic masking tape is available in widths of 1/8", 1/4", 1/2", 3/4", and 1". This tape, especially the narrow widths, can be stretched to mask a curved area. Plastic masking tape forms a finer edge than standard masking tape. See **Figure 25-45**.

Foam tape is used to mask off hood, door, and deck lid openings. Paint applied to the foam tape is tapered, as compared to paint applied to the masking tape, which makes a hard, right angle edge. Foam tape is shown in **Figure 25-46**.

Liquid Mask

Liquid mask is applied with a spray gun. See **Figure 25-47**. The liquid mask dries to a film on the surface of the vehicle. When painting is completed, the liquid mask is removed by washing it off with water.

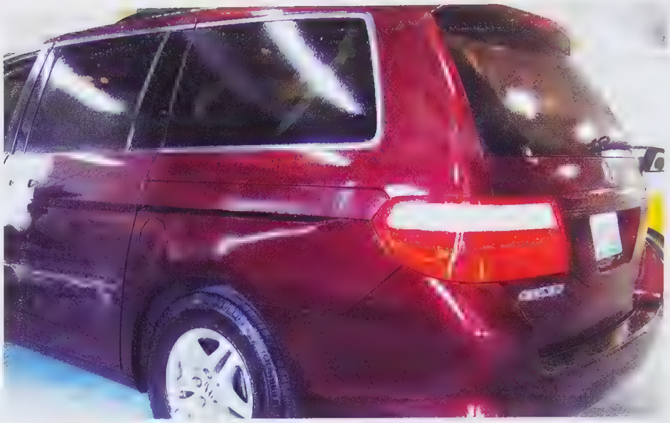


Figure 25-47. *Liquid mask, applied to the quarter panel and rear bumper with a spray gun, protects this vehicle from overspray. Liquid mask washes off with water.*

The liquid mask will protect the wheel wells, frame, roof and wheels. However, it should not be applied closer than 18" to the area that will be painted.

Plastic Sheet

Plastic sheet, shown in **Figure 25-48**, is used to protect large sections of a vehicle during repainting. The sheet is removed from a roll and cut to the required length. It is held in place with masking tape. Plastic sheet also can be used to protect vehicles parked near the work area from overspray.

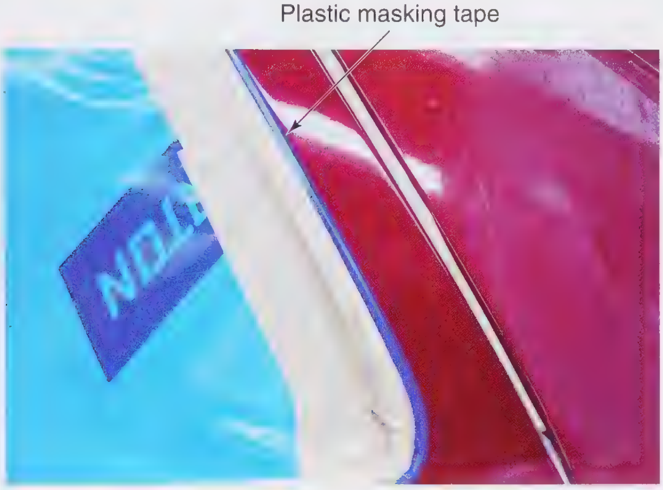


Figure 25-45. *The blue plastic masking tape makes a fine edge. It is placed adjacent to the spray area.*

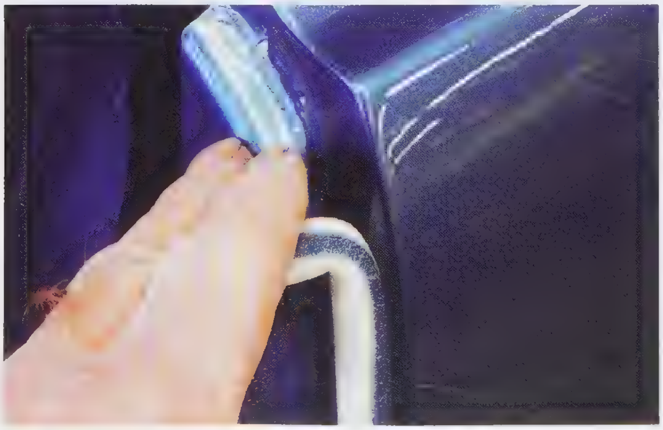


Figure 25-46. *Foam tape makes an invisible edge when masking a door opening.*

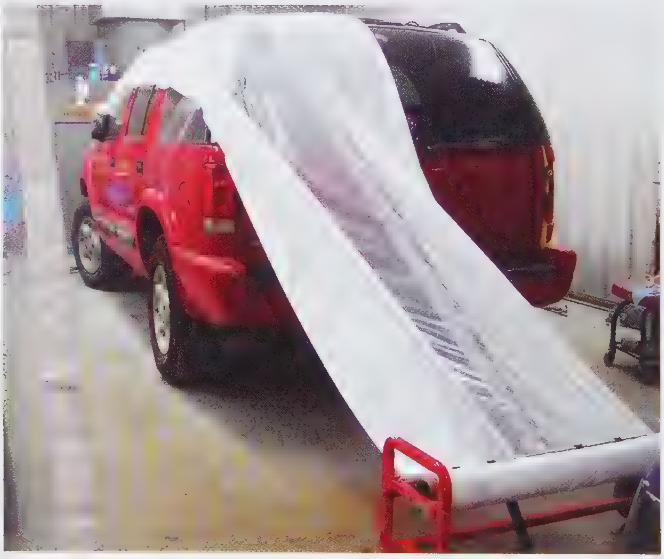


Figure 25-48. *Plastic sheet will protect this SUV during painting. This driver side of the vehicle will not be painted.*

Rope

Moldings around glass often fit tight against the paint. To prevent a paint edge around the molding, the molding can be raised. Nylon rope, shown in **Figure 25-49**, is placed under the molding, raising the molding off the paint. This allows the under-molding area to be sanded and painted. Various diameters of rope are available. The rope is cut to the desired length.

Another way to raise a window molding is with rigid tape. The rigid tape consists of two portions: a rigid section and an adhesive section. The rigid section is slipped under the molding and the adhesive side is attached to the window, raising the molding. See **Figure 25-50**.

Aluminum Foil

Aluminum foil is a great way to mask odd-shaped or oily components, such as a drive train part or suspension piece. The aluminum foil can be easily shaped to fit around virtually anything. Masking tape does not adhere to oily surfaces, but foil can be crimped to fit.

Mixing and Straining Supplies

Properly mixing and straining paint is critical to the outcome of the refinishing operation. Specially designed mixing cups and strainers are used with automotive paints.

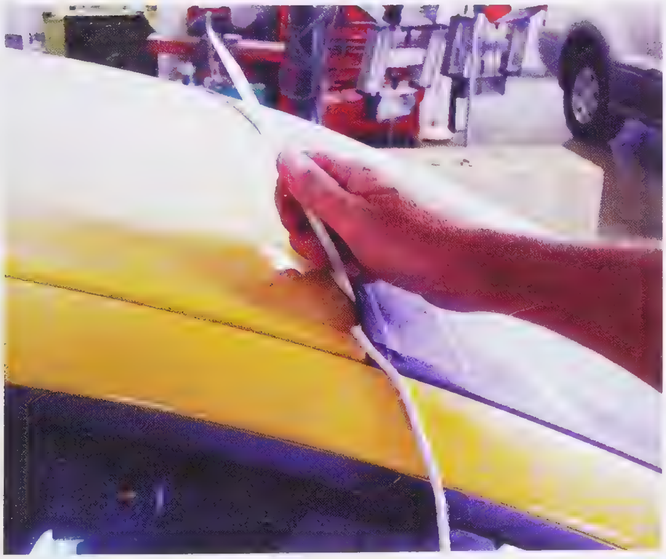


Figure 25-49. *Rope is inserted under the molding to allow painting under the molding, making an invisible edge.*

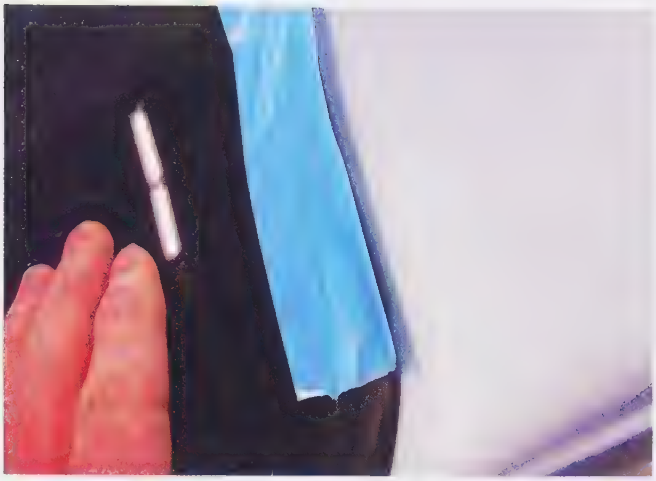


Figure 25-50. *Rigid tape raises the molding, allowing paint to be applied under the molding.*

A disposable ***mixing cup*** is shown in **Figure 25-51**. Various mixing ratios are printed right on the cup. The advantage of disposable cups is that the painter does not have to waste time cleaning the cup after use.

Paint strainers are used to filter the mixed paint as it is poured into the paint gun cup. Some strainers are reusable, others are disposable. Reusable paint strainers are cleaned by rinsing them in the spray gun cleaner. Disposable strainers are thrown away after use. Cotton mesh strainers may shed cotton fibers, contaminating the paint.

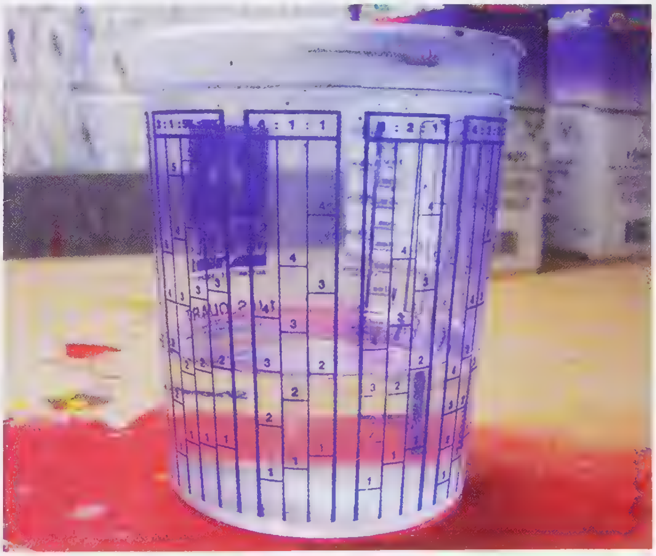


Figure 25-51. *A disposible mixing cup can be used and then thrown away. The various mixing ratios printed on the cup allow it to be used with different types of paint.*

Mixing sticks are used to measure paint components. Universal mixing sticks are marked into equal units. Dedicated mixing sticks are marked into part ratios for a particular type of paint. A universal mixing stick is shown in **Figure 25-52**.

Buffing Materials

Buffing materials include compounds, polishes, and glazes. Compounds and polishes contain abrasives that cut smoothly but may leave visible swirl marks in the paint. If you put compound on your fingers and rub them together, you can feel the abrasive grit. Compound will remove 1200-grit sanding scratches.

Unlike compound, you cannot feel the grit in a polish. Polish cuts lightly and leaves faint swirl marks. Polish will remove 2000-grit sanding scratches.

A buffer spins a pad coated with compound or polish. The purpose is to increase the shine by removing faded paint or by smoothing the surface. The cutting action of a compound or polish is determined by the size of the abrasive, but larger abrasives run the risk of making swirl marks or circular gouges in the paint. Swirl marks can also be caused by a pad contaminated with dried compound or polish cutting into the paint.

A glaze does not contain abrasive. A glaze temporarily fills in swirl marks and applies a coating that makes the paint shine. The glaze will gradually wear off by washing or exposure to rain. Hand glaze is applied with a soft cloth or paper towel and wiped off. Machine glaze is applied with a foam pad. Hand glaze and machine glaze do the same job, they both fill swirl marks and make the paint shine. Hand glazing does not sling material all over the vehicle like machine glazing can, but machine glazing is faster than hand application.

Due to the increasing amounts of recycled content in today's paper, a coarse paper towel may cut fine scratches into paint. Rather than using paper or a generic shop rag, the technician should use a ***detail cloth***. A detail cloth is a soft cloth rag that will not damage clean paint. The detail cloth is the preferred way to apply and wipe off hand glaze.

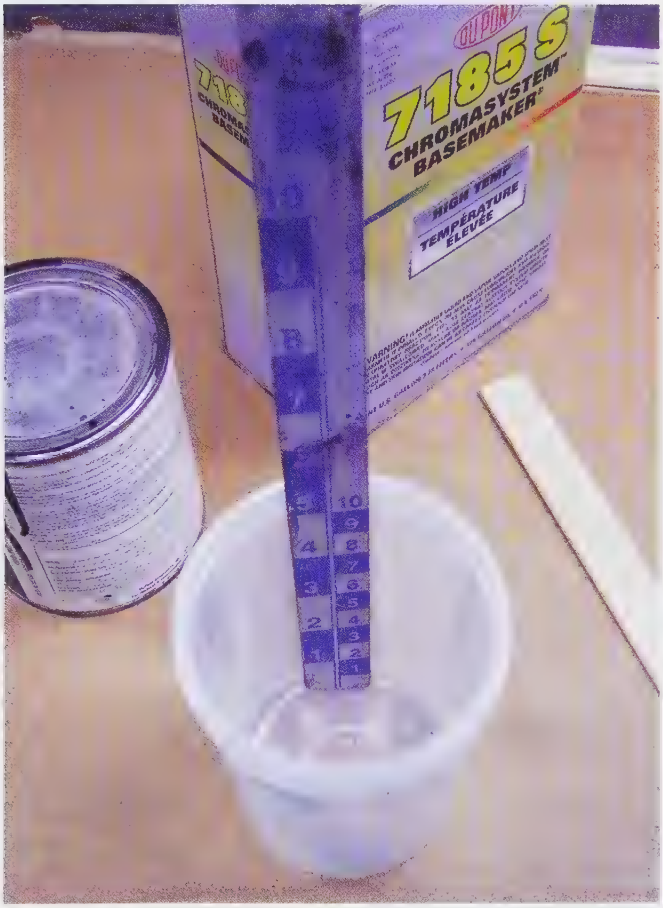


Figure 25-52. *This is a universal mixing stick. The increments can be used for several types of paints.*

Summary

- Thermoplastic paint dries by evaporation of the solvent.
- Thermoset paint dries by evaporation of the solvent and reaction.
- Paints may be solvent borne—lacquers and enamels—or waterborne.
- Lacquers are thinned. Enamels are reduced.
- Paint is made up of binder, pigment, solvent, and additives.
- Pigments are made from fine powders and determine the color of the paint.
- The solvent dissolves the binder and carries the pigment.
- Additives are used to give paint special capabilities or to prevent problems.
- VOC means volatile organic compound. It is a potential air pollutant.
- A hardener or catalyst causes crosslinking.
- Topcoats can be single-stage, basecoat/clearcoat, or tri-coat.
- Undercoats consist of etchers, primers, surfacers, and sealers.
- Sandpaper can be classified as pre-paint—coarse to fine grits—24 to 1000; and post-paint—very fine grits–1200 to 2000.
- Sandpaper may be dry or wet/dry.

Review Questions

Please do not write in this textbook. Place your answers on a separate sheet of paper.

1. The two types of paint are thermoplastic paint and ______ paint.
2. Explain how a thermoplastic paint dries.
3. A hardener causes polymerization. True or False?
4. The letters VOC stand for ______.
5. ______ are thick resins that, when mixed with solvent, form a matrix to evenly disperse and contain the paint's pigment.
6. Aluminum flakes reflect light. True or False?
7. The pearl effect is caused by ______.
8. A lacquer is thinned, an enamel is ______.
9. Explain viscosity.
10. Different types of reducers allow paint to perform differently under different conditions. True or False?
11. Once paint is mixed with hardener, the mixture has a(n) ______.
12. Explain why the reducer and shop temperature must be matched.
13. Crosslinking cannot take place at temperatures below ______.
14. The basecoat dries to a shiny finish. True or False?
15. The type of paint system that has an intermediate pearl coat is called a(n) ______.
16. Cleaning and phosphating are part of ______.
17. Epoxy primer is a dual-use primer/sealer, able to adhere to bare metal or existing paint. True or False?
18. A(n) ______ provides hold out.
19. P600-grit sandpaper is coarser than P400-grit sandpaper. True or False?
20. Polish contains grit that can be felt. True or False?

ASE-Type Questions

1. Technician A says that paint with a viscosity of 18 seconds is thicker than paint with a viscosity of 22 seconds. Technician B says that paint with a viscosity of 22 seconds is thicker than paint with a viscosity of 18 seconds. Who is right?
   (A) A only.
   (B) B only.
   (C) Both A and B.
   (D) Neither A nor B.
2. All of the following are types of thermoset paint EXCEPT:
   (A) Acrylic enamel.
   (B) Lacquer.
   (C) Urethane.
   (D) Polyurethane.
3. Technician A says that P400 and 400-grit sandpaper are not necessarily the same coarseness. Technician B says that CAMI system rated sandpaper has a P prefix. Who is right?
   (A) A only.
   (B) B only.
   (C) Both A and B.
   (D) Neither A nor B.
4. Lacquer paint dries by ______.
   (A) crosslinking
   (B) oxidation
   (C) evaporation of lacquer thinner
   (D) evaporation of enamel reducer
5. Which of the following components of reducer is the first to evaporate?
   (A) Dilution solvent.
   (B) Adhesion solvent.
   (C) Leveling solvent.
   (D) Tertiary solvent.
6. The spray booth temperature is 65°. Technician A says to use a low-temperature reducer. Technician B says to use a high-temperature reducer. Who is right?
   (A) A only.
   (B) B only.
   (C) Both A and B.
   (D) Neither A nor B.
7. The hardener in paint is a(n) ______.
   (A) lacquer
   (B) isocyanate
   (C) pigment
   (D) acrylic
8. Crosslinking will not occur at temperatures below ______.
   (A) 90°F (32°C)
   (B) 80°F (26.6°C)
   (C) 70°F (21°C)
   (D) 60°F (15.5°C)
9. A can of hardener has been opened. Technician A says the hardener has a shelf life of seven days. Technician B says there is no shelf life. The hardener would still be good. Who is right?
   (A) A only.
   (B) B only.
   (C) Both A and B.
   (D) Neither A nor B.

10. Which of the following parts should be painted with a flex agent?
    (A) Steel fender.
    (B) Urethane bumper cover.
    (C) Steel bumper.
    (D) Aluminum hood.
11. Technician A says that red pearl topcoat is a poor hider. Technician B says that clearcoat contains no pigment. Who is right?
    (A) A only.
    (B) B only.
    (C) Both A and B.
    (D) Neither A nor B.
12. All of the following are part of a tri-coat EXCEPT:
    (A) solid base color.
    (B) translucent pearl coat.
    (C) single-stage.
    (D) clearcoat.
13. Bare metal has been exposed to the air for 24 hours. Technician A says to apply one coat of epoxy primer. Technician B says to apply two coats of self-etching primer. Who is right?
    (A) A only.
    (B) B only.
    (C) Both A and B.
    (D) Neither A nor B.
14. All of the following are uses of sealer EXCEPT:
    (A) adhesion promoter.
    (B) to make a uniform color.
    (C) provide hold out.
    (D) form the topcoat.
15. A vehicle to be refinished has road tar contamination. Technician A says to use a pre-paint solvent. Technician B says to use a pre-sanding solvent. Who is right?
    (A) A only.
    (B) B only.
    (C) Both A and B.
    (D) Neither A nor B.

Chapter 26

Paint Mixing and Reducing

Objectives

After studying this chapter, you will be able to:

- Know where to find a paint code on a vehicle.
- Understand how to use the paint code to obtain the paint part number.
- Understand the importance of thoroughly stirring tints.
- Explain how to mix a color.
- Know how to reduce paint by volume, percentage, and weight.

Technical Terms

comprehensive tint system
cumulative formula
digital scale
factory pack color
graduation
jobber
overpour
paint code
paint formula
paint part number
paint shaker
quantitative formula
single tint system
surface cure
tint mixing bank
viscosity
volume

Introduction

This chapter will cover paint mixing and paint reduction. Paint mixing involves combining various tints to create a specific color. Paint reduction prepares paint for spraying. Both of these operations must be performed before a vehicle can be painted. For proper color match and paint performance, all instructions for mixing and reducing paint must be followed carefully.

Paint Mixing

This section explains how to locate a vehicle's paint code and the paint part number. With the paint code or paint part number, the technician can access the color formula. The color formula is a list of the tints used to make a color. The technician uses this formula to combine the tints to create the desired color.

Paint Code

All vehicles have a paint code. The ***paint code*** consists of letters, numbers, or a combination of letters and numbers that represent the color of the vehicle. The paint code location differs from one vehicle type to another. **Figure 26-1** shows where the paint code is located on various vehicles. The paint code information is presented in different ways, depending on the vehicle manufacturer.

If the vehicle has a two-tone paint scheme, there will be two paint codes displayed. The date of vehicle manufacture will also be listed on the paint code label or tag. This is important because a vehicle's manufacturer may use the same paint code for different colors on different model year vehicles.

Paint Part Number

The paint code and the vehicle model year are used to find the paint part number. The ***paint part number*** is the number given to a color by a specific paint manufacturer. The paint part number will be different for different paint manufacturers.

One way to find the paint part number is to use a paint manufacturer's color chip book. See **Figure 26-2**. The color chip book contains small samples, or chips, that show what each color looks like. The chips are arranged by vehicle manufacturer, with each model year listed on a separate page.

To find a paint part number, select the proper vehicle year and model in the chip book. Then find the paint code on the page. See **Figure 26-3** for an example. Paint part numbers may also be found by looking at a paint code book, **Figure 26-4**. This book does not contain color chips. To use this book, look up the vehicle manufacturer, vehicle year, and paint code.

The paint part number can also be found using a computer loaded with a paint code/paint part number CD. The vehicle manufacturer, vehicle year, and paint code are entered into the computer. The system examines its database and identifies the paint part number. **Figure 26-5** shows an example of this type of search.

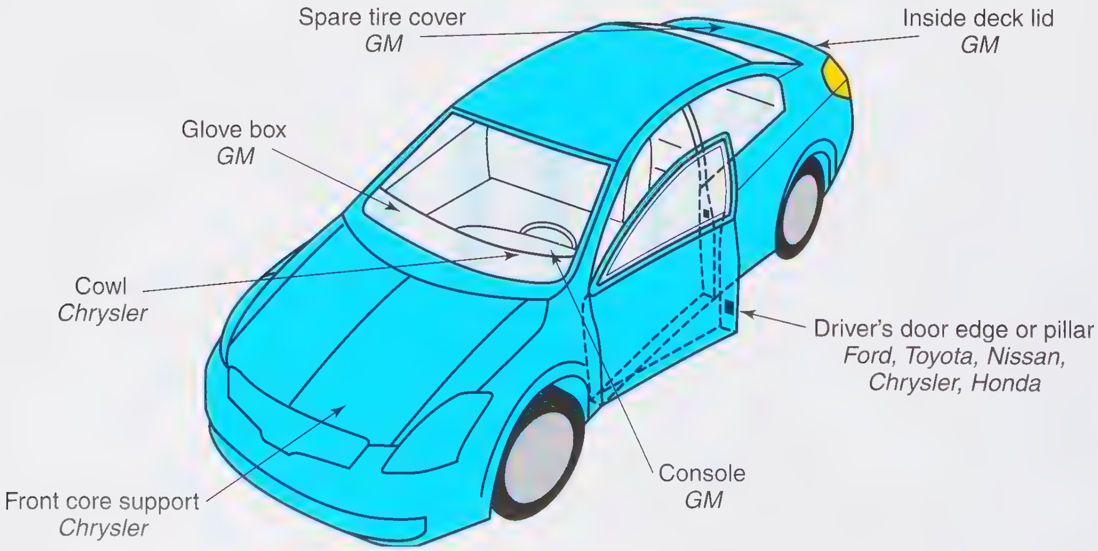


Figure 26-1. *This chart lists the locations of paint codes on various vehicles.*

SHERWIN WILLIAMS
Automotive Finishes
COLOR BOOK

Figure 26-2. *A paint chip book contains small samples of each vehicle manufacturer's colors.*

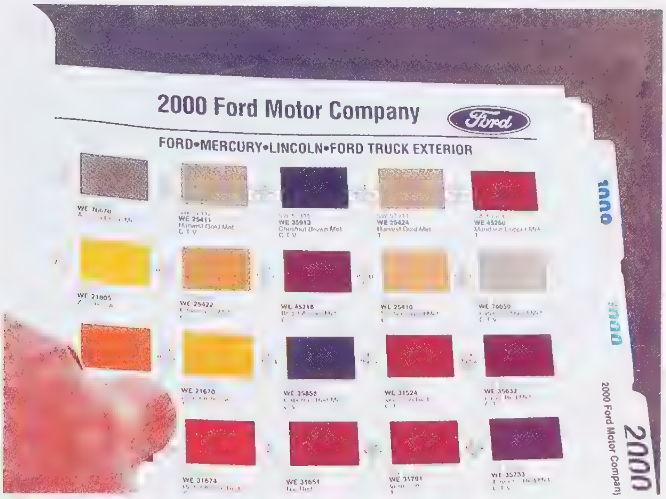


Figure 26-3. *Match the color to the paint code in the paint chip book to determine the paint part number.*

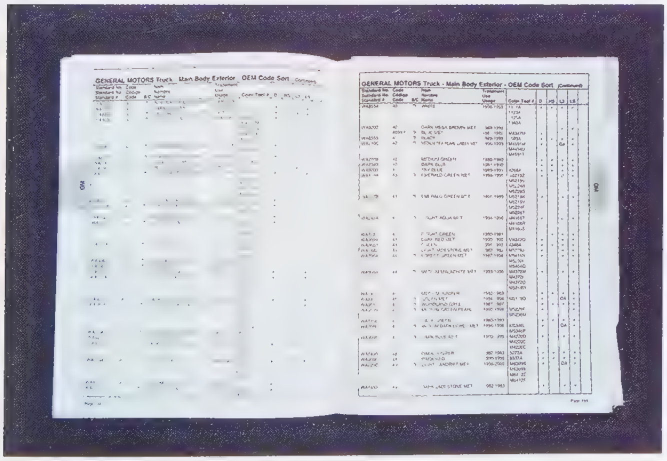


Figure 26-4. *This book lists paint codes and corresponding paint part numbers, but color samples are not included.*

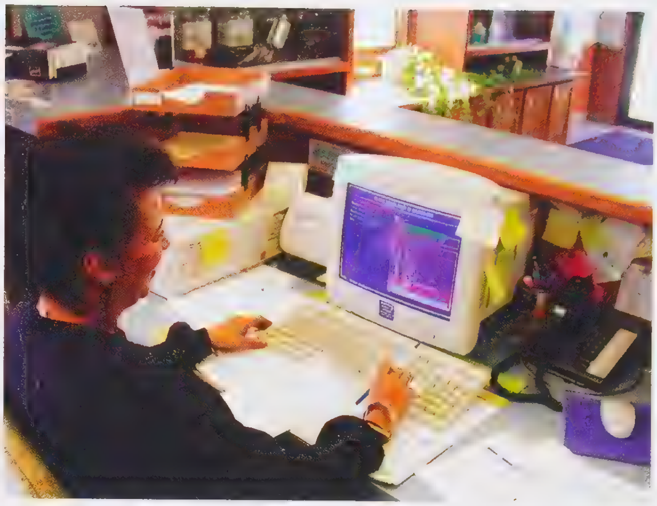


Figure 26-5. *This body shop supply company technician is looking up a paint part number for an employee.*

Some paint manufacturers' paint formulas are available on the Internet. To access these formulas, the vehicle manufacturer, year of manufacture, and paint code are entered into the computer. The computer will list the paint part number.

Alternate Paint Part Numbers

The color on some vehicles with the same paint code, model year, and manufacturer may be slightly different. There are many possible reasons for the differences. For example, vehicles built at different factories may be sprayed with paint from different paint manufacturers. Also, the environmental and spraying conditions and equipment may vary from one factory to another.

To account for these differences, some paint codes may have ten or more alternate paint part numbers. Alternates are variations of a paint color for a specific paint code. To find the correct alternate, the paint technician can consult a deck of alternate color chips. The deck of alternate color chips contains all the alternates for a certain paint part number. The paint technician can compare the color of the vehicle with the various colors of the chips and choose the chip that best matches the color of the vehicle. Each alternate will have a slightly different formula than the others. See **Figure 26-6**.

Another way to find the correct alternate is to use the vehicle's VIN, as well as the paint code. The VIN will allow the computer to determine which factory the vehicle was assembled at and when. The computer will search data to find the correct alternate. This system may be 85% effective at delivering an acceptable color match.

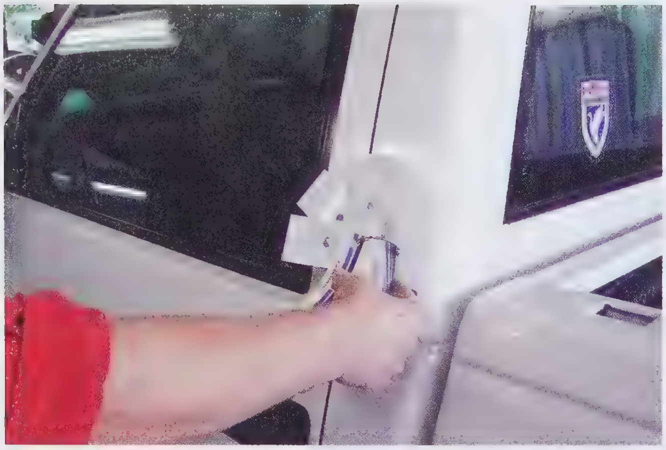


Figure 26-6. *The paint technician is visually comparing white paint chips to find the best match.*

Vehicles may have a different color under the hood than on the exterior body panels. This is because the color used under the hood does not contain the metallic or pearl that an exterior color may have. The underhood color may be found in a paint chip book. Underhood colors are shown in **Figure 26-7**. The underhood color should be mixed and applied when painting underhood components, such as the radiator support, apron, or underside of the hood. This will allow the underhood color to match the original, but it will involve additional labor.

Paint Sources

Body shops may obtain paint from a supplier called a ***jobber***. A jobber may sell one or more brands of paint. Some body shops do not have an in-house mixing system, also called *intermix*, so they rely on the jobber. The body shop provides the jobber with the paint part number and the specific paint color is mixed at the jobber's store. The jobber then delivers the mixed paint color to the body shop. In some cases, the jobber will have a factory pack color available. A ***factory pack color*** is mixed by the paint manufacturer. The factory pack paint color may be a better color match than a jobber mixed color. Some body shops prefer factory pack paint and request it when it is available.

Most large body shops have their own mixing systems. The shop obtains the tints from the jobber and the colors are made at the body shop. Whether the paint colors are made at the jobber's store or at the body shop, they are all carefully mixed following a specific formula. The formula lists the precise amounts and types of tints that are combined to make the color.

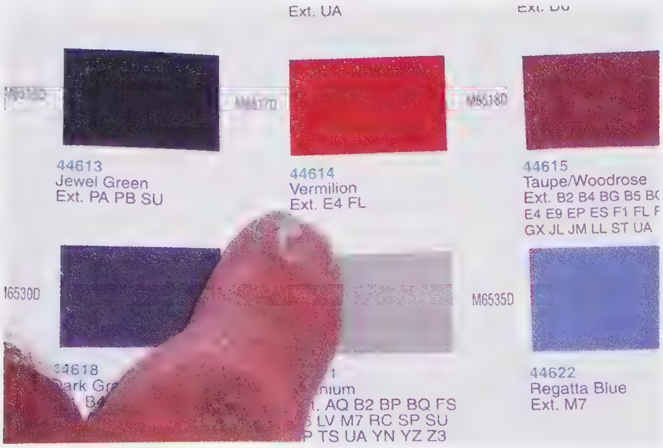


Figure 26-7. *Several exterior paint codes may share the same underhood color.*

Paint Mixing Equipment

Paint mixing equipment can be found in a jobber's store or a body shop's paint department. This equipment includes a scale, mixing bank, mixing lid, paint shaker, paint mixing supplies, and paint can labels. Paint can be mixed by weight. A ***digital scale***, **Figure 26-8**, is used to weigh tints.

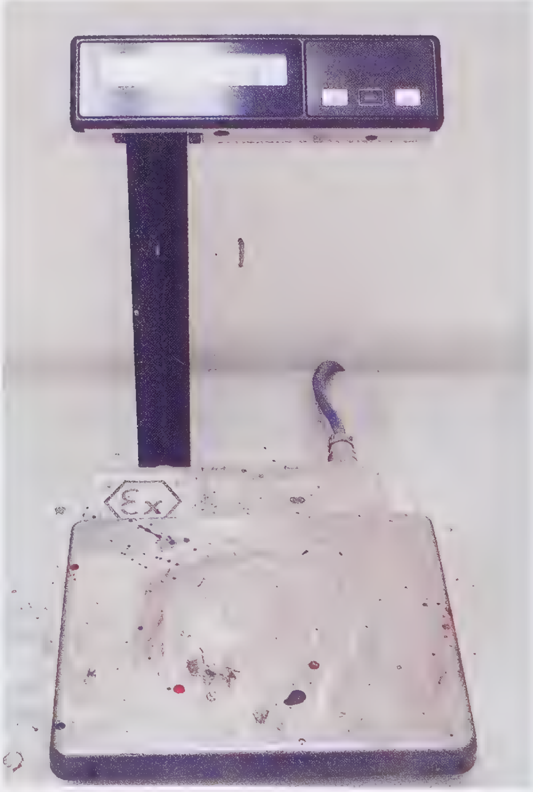


Figure 26-8. *This digital scale measures to hundredths of a gram.*

This type of scale is extremely precise. It can measure to one-hundredths of a gram. Digital means that the readout is given as a number rather than using a sweeping needle. To check a digital scale for accuracy, place a nickel on the scale. The scale should register five grams.

To use the scale, place an empty paint can on the scale. Zero the scale (set readout to zero) with the can in place. In this example, pressing the bar just above the digital readout zeros the scale. See **Figure 26-9**. Zeroing the scale eliminates the weight of the can in weighing the tints. The scale shown in **Figure 26-10** includes a monitor to display the paint formulas. The monitor is linked to a computer that stores the paint formula information.

A ***tint mixing bank*** is designed to stir the tints, **Figure 26-11**. The mixing bank uses an electric motor to rotate stirring bars. After a can of tint is clamped into a mixing lid, the stirring bars turn a shaft connected to a paddle to thoroughly mix the tint. See **Figure 26-12**. The tint can be easily poured through the lid's spout by pushing down on the handle. Another effective way to thoroughly mix paint components is with a ***paint shaker***. The paint shaker depicted in **Figure 26-13** can accommodate a gallon, quart, or pint can.

WARNING

Read the paint can label or refinish manual to determine the mixing ratio. Always measure the amounts of paint, hardener, and reducer. Never estimate these amounts.

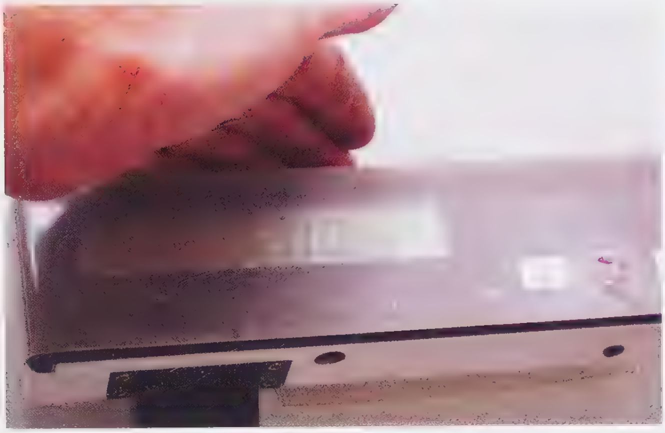


Figure 26-9. *Pressing the bar at the top of the scale sets the scale to zero. A plastic cover protects the scale readout screen from splashed paint, causing the numbers to look out of focus.*

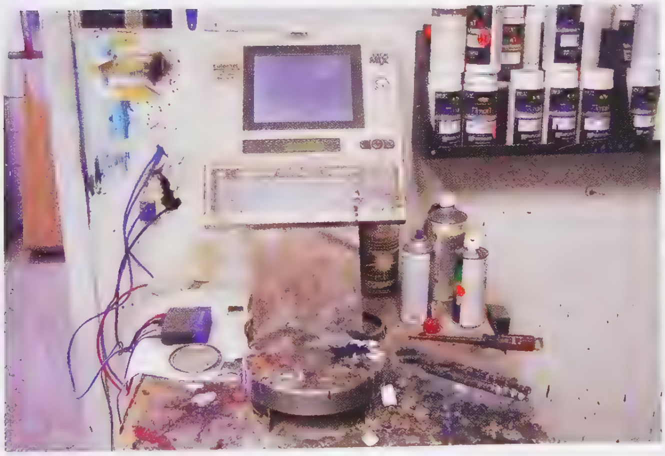


Figure 26-10. *This monitor displays the weight on the scale and the paint formula. It can be used to mix and reduce paint.*

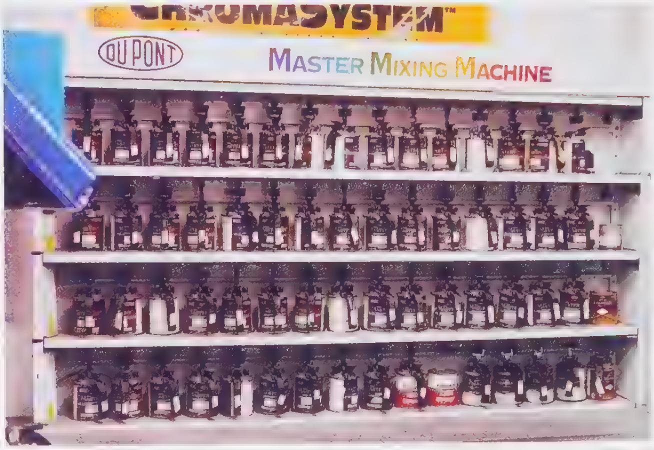


Figure 26-11. *All the tints needed to make automotive paint colors are included in the mixing bank.*

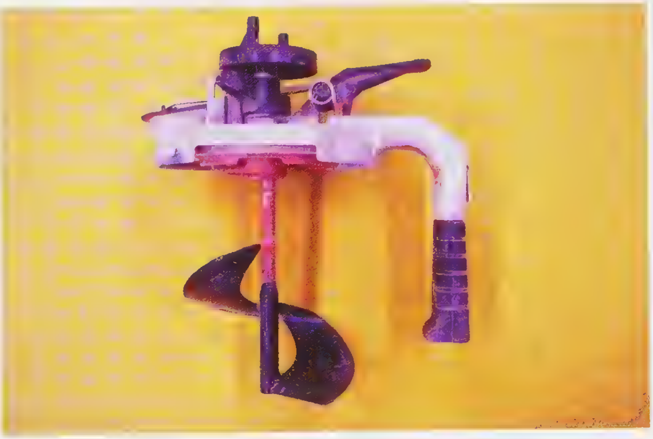


Figure 26-12. *The mixing lid has a simple gear to engage the stirring bar which rotates the paddle inside the paint can. Pressing down on the thumb trigger near the handle retracts the pour spout cover, allowing tint to flow out of the can.*

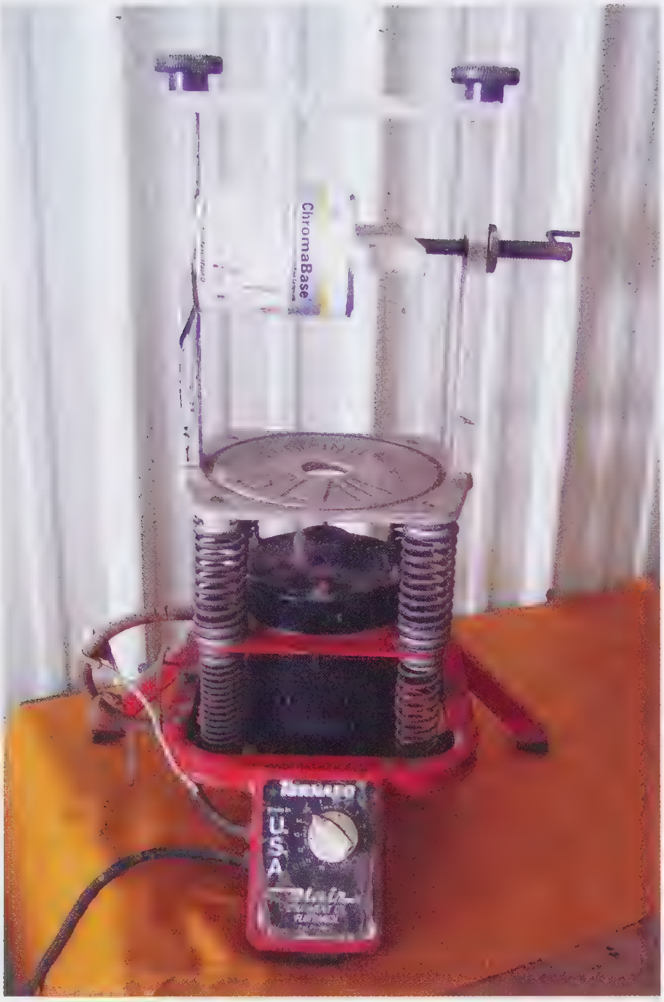


Figure 26-13. *The paint shaker agitates the paint into a homogeneous state. Pint and quart cans are mounted sideways and gallon cans are mounted upright. Do not shake waterborne paint.*

Paint Mixing Supplies

Paint mixing supplies include tints, binders, and balancers. The most common types of tints and mixing supplies include:

- High-strength tint—A small amount of high-strength tint will cause a change in color. A large amount will cause a dramatic color change.
- Low-strength tint—Low-strength tints are used to fine-tune the color matching process. A small amount of low-strength tint will have a subtle effect on the color. A large amount will cause a slight change. Paint manufacturers developed low-strength tints to make slight changes in colors to aid in color matching accuracy. If a high-strength tint were used instead, the amount required may be less than the scale can measure. A low-strength tint allows the required amount to be weighed by the scale.
- Powder pearl—Dry powder pearl adds the subtle, glowing effect of mica flakes to the basecoat. Translucent mica flakes allow some of the color of the basecoat to show through. Various shades of pearl, such as blue pearl or green pearl, become visible. Powder pearl can be squeezed from the bottle or spooned into the mix.
- Metallic tint—Metallic tint gives a mirror-like effect to the basecoat. Thousands of polished aluminum flakes are the key ingredient in a metallic tint. The flakes reflect light, but unlike mica in powder pearl, they do not allow the base color to show through. There are many types of metallic tint, and the effect depends on the size of the aluminum flake. Flake sizes range from coarse (large) to fine (small). Small metallic particles tend to be brighter than larger metallic particles.
- Binder—Binder is the resin component in paint and is dissolved by solvent. Binder forms the film when the paint dries. A single-tint paint system will need to have a binder listed in the paint formula. A comprehensive tint paint system has the binder included as part of the tint, so a separate binder is not required.
- Balancer—A balancer may have two jobs. In some types of paint, balancer is used as a neutral filler to correct the ratio of pigment to binder. To achieve color match, a certain amount of pigment is required. This pigment will require a certain amount of binder. If the ratio of pigment to binder is not correct, a balancer is added to the formula. A balancer is also used to control the uniform orientation of aluminum flakes in a metallic color. The balancer will help position flakes after the paint is sprayed on the substrate. Sometimes a balancer is called a flake control.

There are two basic types of tint systems: comprehensive tint systems and single tint systems. A ***comprehensive tint system*** contains pigment, solvent, binder, and additives. In a ***single tint system***, the tint contains pigment and solvent, or in the case of powered pearl, pigment only. A paint manufacturer that supplies single tints will have separate balancer, binder, or additives as part of the paint formula.

Tints will settle and separate, so tints must be stirred before mixing. Most shops and jobbers stir the tints for fifteen minutes early in the morning and again after lunch. If a paint is about to be mixed, the tints are stirred again before being added to the mix. Always stir the tints to ensure that each tint is uniform.

WORKING GREEN

To provide an adequate amount of ventilation in the paint mixing room, the U.S. EPA suggests the installation of local exhaust vents near sources of emissions (e.g., mixing bench, gun cleaner). They further recommend locating sources of emissions in the same general area to maximize ventilation effectiveness. The design of the ventilation system should draw vapors away from workers and electrical equipment (e.g., switches, ventilation fans, lights, and telephones), and must be approved for Class I, Division 1 (explosive) environments.

Paint Formula

The ***paint formula*** is the recipe for a color. The paint formula contains a list of tints and the weight of each that should be added when mixing a specific paint color. The list of tints can be quantitative or cumulative. A ***quantitative formula*** lists the weight of each tint required. A ***cumulative formula*** lists the weight of the entire mixture as each tint is added to the paint. **Figure 26-14** shows both cumulative and quantitative formulas. The cumulative formula is most useful because it lists the progressive weight as each tint is added to the formula. The technician simply adds the specified amount of each tint.

The paint formula can be accessed in two ways. **Figure 26-15** shows a microfiche reader and a microfiche. The microfiche data is organized by paint part number. **Figure 26-16** shows a computer display of a paint formula. The computer can be part of the scale or a stand-alone unit.

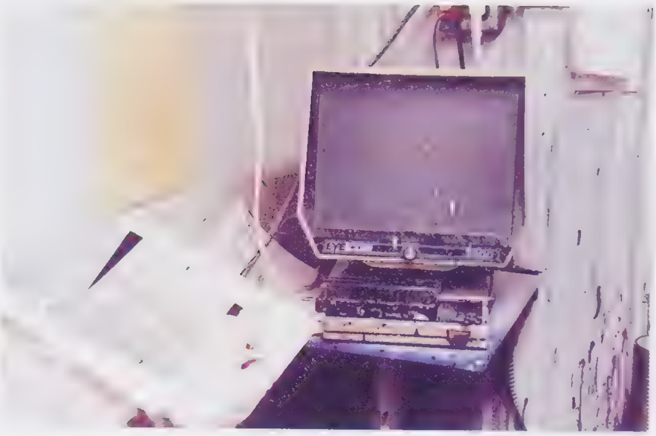


Figure 26-15. *The microfiche, stored in the book on the left, is inserted into the reader. The reader magnifies the paint formula onto the screen.*

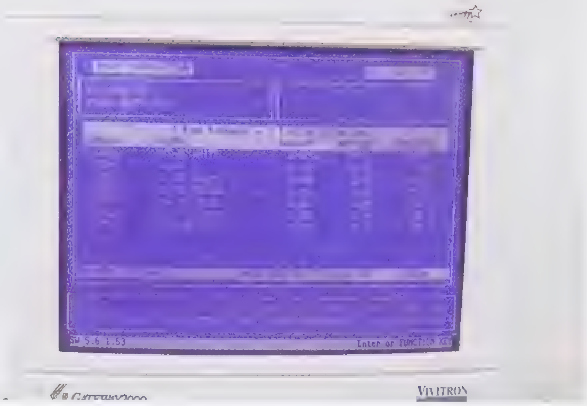


Figure 26-16. *This computer is a stand-alone unit, but it is located close enough to the work area to allow the technicians to read the formula and mix tints on the scale.*

Turquoise Green			
Qty: 1 Gallon			
Code	**Color**	**Cumulative**	**Part**
DMC923	Green Sh	308.0	308.0
DMC901	Strong T	746.0	438.0
DMC905	Lemon Ch	1404.8	658.8
DMC900	Strong W	4018.8	2614.0
DMC999	Mixing C	4385.2	366.4
DT885	Reducer	4914.8	529.6

Figure 26-14. *This paint formula is given in both cumulative and quantitative formats. Many paint manufacturers use the terms part or noncumulative (non cum) to designate quantitative paint formulas.*

In most cases, the computer can be used to print out the paint formula. With a microfiche reader, the formula is often copied down by hand and taken to the scale.

Color Creation

Paint mixing is a straightforward operation if the following guidelines are observed:

- Stir the tints for 15 minutes twice a day. An easy way to remember this is stir the tints at the beginning of the workday and again when starting work after lunch.
- Before a new can of tint is placed on the mixing bank, shake the tint for 30 minutes on the paint shaker.
- If a tint sits on a shelf for an extended period of time, double filter the reduced paint when pouring into the spray gun cup (use two filters instead of one). As the tint ages it may form grit. Double filtration screens out the grit.
- When a large amount of paint is needed, enough to paint 3 or more panels, mix a small amount of paint first. Spray this paint on the vehicle to determine how well the paint covers and hides the undercoat. Once the coverage is determined, the necessary amount of paint can be mixed. This prevents mixing too much paint and wasting materials.
- Do not use metal cans to mix or reduce waterborne paint.
- Always stir the tints for at least five minutes before pouring. The heavier components in tints can settle out during storage. This will cause the tint to be inconsistent in color. The tint in the upper region of the can will be a slightly different color than the tint in the lower region of the can. Pouring nonuniform tint from an unstirred can will make a mismatched color; not only for the color mixed but for future colors as well. The entire can of tint will not be the right color if it is poured before it is properly stirred.
- Remove any dried paint that accumulates on the spout of the mixing lid. Removing the dried paint keeps contaminants out of the mixed paint.
- Recheck the tint number before pouring to make sure it is correct. Know how much tint will be added.
- Concentrate while pouring. It is easy to become distracted and add too much tint, so stay focused! Near the end of a formula, only a drop or two of tint will be needed.
- Add tints to the center of the paint can. Do not spread them out. Tints added in a concentrated mass to the center of the can are easier to remove.
- Use a clean paint can. A can of used paint may contain dried paint. The dried paint may contaminate the tints.

To mix a color, decide on how much paint is needed. Obtain a clean paint can. Place the can on the scale and then zero the scale by pressing the bar. **Figure 26-17** shows a formula to make paint. To make a half pint of this color:

1. Add 72.1 grams of part number U7110 to the empty can.
2. Add U7109 until the scale reads 136.2 grams.
3. Add U7120 until the scale reads 190.4 grams.
4. Add U7137 until the scale reads 229.6 grams.
5. Add U7118 until the scale reads 248.8 grams.

Another type of digital scale weighs the tints in a different manner. This type of scale is connected to the paint formula computer. Once the paint technician chooses a formula, a screen on the scale will list the number and amount of the first tint. This type of scale counts down rather than up. The technician adds the first tint until the scale reads zero. In this way the technician does not have to remember the ending weight of each tint. Also, as the added tint approaches zero, the scale warns the technician. The screen on the scale lists the next tint and again the technician adds tint until the scale reads zero. This continues for all of the tints.

An ***overpour*** occurs when more than the required amount of tint is added. In the event of an overpour, you must quickly remove the excess tint. If the tint has been poured so it remains in the center of the can, insert a screwdriver into the excess tint to remove it. The tint will stick to the screwdriver as it is removed from the paint. See **Figure 26-18**.

Some computer-driven scales are capable of compensating for an overpour. The computer will calculate the amount of each tint that must be added to correct the problem. When all the tints have been added, install the lid on the can. Place the can on the paint shaker and shake for 5–20 minutes.

Tint	Cumulative
U7110	72.1g
U7109	136.2g
U7120	190.4g
U7137	229.6g
U7118	248.8g

Figure 26-17. *A paint formula lists the amount of each tint to be combined to make a specific color.*

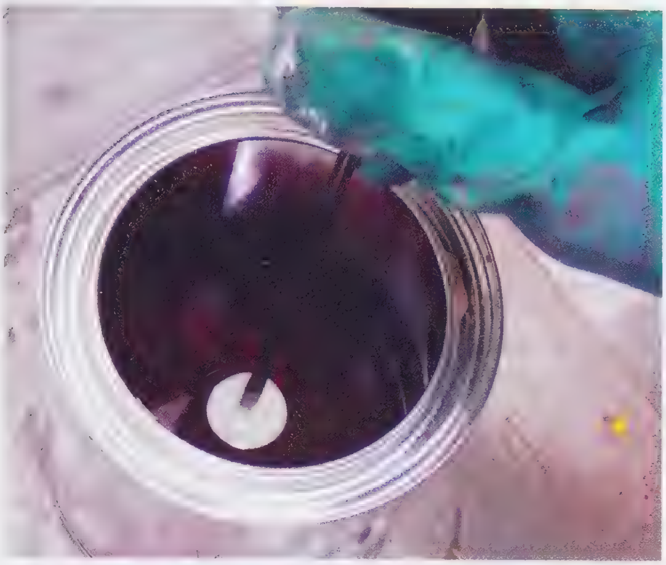
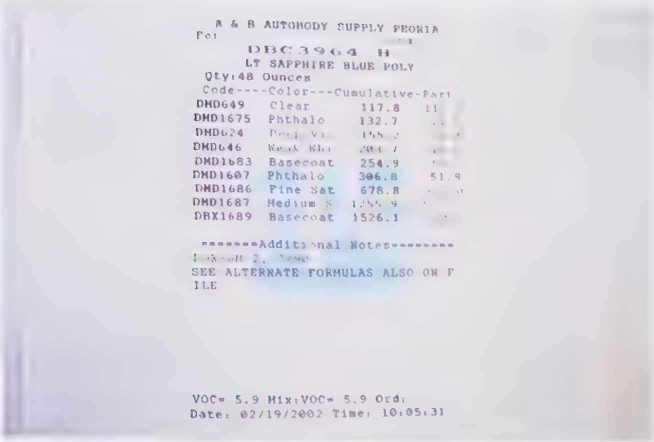


Figure 26-18. *Too much metallic tint has accidently been added to the mix. To correct the overpour, a narrow blade screwdriver is inserted into the metallic tint and slowly withdrawn to extract some of the overpour.*

Obtain a label for the can. The label is usually supplied by the paint manufacturer and lists safety information. **Figure 26-19** shows a blank label. The technician can write the paint part number on the label, as well as the mixing date, the customer's name, and any other pertinent information. On computer-driven systems, a tag can be printed. The tag lists the paint part number and date. Some jobbers and shops also print out the formula on a tag and attach it to the inside of the label. See **Figure 26-20**.

Figure 26-19. *This label lists safety precautions. The paint part number can be handwritten on the label. Often, a printout of the paint part number is glued to the label.*



```
   A & B AUTOBODY SUPPLY PEORIA
For
      DBC3964  H
      LT SAPPHIRE BLUE POLY
 Qty:48 Ounces
 Code----Color---Cumulative-Part
DMD649   Clear      117.8   11
DMD1675  Phthalo    132.7
DMD624   [illegible]
DMD646   [illegible]
DMD1683  Basecoat   254.9
DMD1607  Phthalo    306.8   51.9
DMD1686  Fine Sat   678.8
DMD1687  Medium S   [illegible]
DBX1689  Basecoat   1526.1

=======Additional Notes=========
[illegible]
SEE ALTERNATE FORMULAS ALSO ON F
ILE

VOC= 5.9 Mix:VOC= 5.9 Ord:
Date: 02/19/2002 Time: 10:05:31
```

Figure 26-20. *The formula sticker is attached to the inside of the paint can label.*

Paint Reduction

Paint reduction readies the paint for spraying. Paint reduction has two steps: diluting paint to a sprayable viscosity and, if required, adding hardener. This section explains two ways to reduce paint, by volume or by weight. Proper paint reduction is essential to successful painting. Be sure to use a container that will not be damaged by paint or reducer. Some types of plastic will melt when exposed to reducer.

Stirring

Paint must be uniform before it can be reduced. This means that all paints must be thoroughly stirred before reducing. The heavier components in paint settle out, especially if the paint can has been sitting on a shelf for months or years. Surfacer and metallic paints often have a mass of settled-out material on the bottom of the can. Place the can on a paint shaker or open the can and stir the paint until it is all the same consistency.

CAUTION

Never shake waterborne paint. Shaking will put air bubbles into the paint, which will cause surface defects when the paint is sprayed.

If the solids in a can of surfacer have settled, push the paint stick into the settled material to scrape all the material off the bottom of the can. As you stir the surfacer, the settled material will gradually dissolve into the paint. Some paint technicians poke holes around the lip of the can to allow paint that slops out while stirring to drain back into the can. Place the lid back on the can of any unused paint that will be saved. Tap the lid in place to secure it. An unsecured lid will allow solvents to escape, eventually ruining the remaining paint.

Reducer Type

The type of reducer used must be matched to the spray booth temperature. For the sprayed paint to perform consistently at different spray booth temperatures, a different reducer is required for different temperatures. Consult the paint manufacturer's recommendations for the proper reducer for a specific temperature. In general, use a low-temperature, fast-drying reducer when the spray booth temperature is 60°–70°F (15.5°–21.1°C). A mid-temperature, normal-drying reducer should be used when the spray booth temperature is 70°–85°F (15.5°–29.4°C). If the spray booth temperature is above 85°F (29.4°C), a high-temperature, slow-drying reducer should be used. Selecting the proper reducer is important for consistent paint performance.

Hardener Type

Paint manufacturers may rate hardener by temperature conditions, in the same way they rate reducer. A temperature-rated hardener may have a part number that ends with the numbers of the intended temperature range, such as 75. The correct temperature-rated hardener is added to the clearcoat or single-stage enamel. More commonly, hardeners are rated by their intended usage—overall, panel, or spot.

A hardener rated as overall causes a slower surface cure than a panel- or spot-rated hardener. To give the tech enough time to paint an entire vehicle, the paint must stay wet long enough to allow overspray from adjacent panels to melt in. If the paint dries too soon, an unsightly layer of dust-like overspray remains on the surface. The slower surface cure of an overall reducer gives overspray enough time to melt in.

Surface cure is the amount of time that paint will stay wet enough to accept/absorb overspray. Surface cure is not the same as cure. In curing, the paint will cross-link and become durable. The slow surface cure speed of an overall hardener allows each coat to stay wet long enough to let overspray sink in.

When painting a much smaller area, a hardener with a short wet time is desirable. A spot-rated hardener is added when an area, one panel or less in size, is painted. Paint or clearcoat with a spot-rated hardener mixed in will surface cure rapidly.

Somewhere in between the fast surface cure of a spot-rated hardener and the long wet time of an overall-rated hardener is the panel-rated hardener. A panel-rated hardener is added when 1-3 panels are sprayed at the same time. A panel-rated hardener is a compromise between an overall hardener and spot hardener. Some paint manufacturers may only offer two hardeners: overall and panel/spot.

Viscosity

Viscosity is an indication of paint's liquid thickness. Paint viscosity is measured with a viscosity cup. To measure viscosity, immerse the cup in the paint. Once the cup is full, lift it out of the paint. Measure the time it takes for the paint to flow out of the cup's hole, starting when the paint begins flowing from the hole and ending with the first break in the paint stream. **Figure 26-21** shows a viscosity cup. This viscosity cup holds 100 ml of paint. The hole in the bottom of the cup is 4 mm in diameter. The time, measured in seconds, for the paint to flow out of the hole in the bottom of the cup is the viscosity. Thick paint has a greater resistance to flow than thin paint, so its flow rate is slower. Thin paint has less resistance to flow than thick paint, so its flow rate is faster. Most paint is sprayable at a viscosity range of 18–22 seconds. To maintain the cup, clean it after each use and do not allow dried paint to clog or decrease the size of the hole.

A viscosity greater than the sprayable range means the paint is too thick. A viscosity less than the sprayable range means the paint is too thin. With two-component paints, paint and reducer should be added as needed to achieve the desired viscosity. If the paint consists of three or more parts and the viscosity measurement

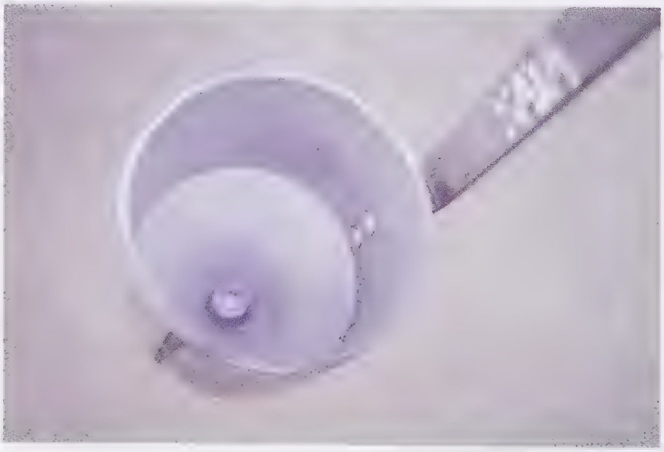


Figure 26-21. *The viscosity cup has a hole in the bottom. The time required for a full cup of paint to flow through the hole is measured in seconds. Most paint is sprayable at a viscosity range of 18–22 seconds.*

is off, the paint will usually be too thick. Add a small amount of reducer to the mixed paint and recheck the viscosity. If this does not correct the problem, you must discard the paint and start over because you cannot determine which part is lacking.

Volume Reduction

Paint can be reduced by ***volume***. Volume can be measured in parts or percentages. Some paints are reduced by a combination of parts and percentages.

Part Reduction

If the reduction instructions for a particular paint call for a mixing ratio of 1:1, or one part of paint to one part of reducer, this ratio applies regardless of the quantity of paint mixed. For example, if 200 ml of reduced paint is required at a 1:1 ratio, 100 ml of paint and 100 ml of reducer are combined. If 64 oz of reduced paint is required, 32 oz of paint and 32 oz of reducer are combined.

To calculate the amounts needed in parts reduction, simply add the number of parts together. In the above example, one part paint and one part reducer equals two parts. Next, divide the required volume by the number of parts (200 ml divided by 2, or 64 oz divided by 2). This gives the volume of each part.

Some paints require more than two parts. In this example, the mixing ratio is 4 parts surfacer, 2 parts reducer, and 1 part hardener. To reduce this paint, add four parts of surfacer, two parts of reducer, and one part of hardener. The same process is used to calculate the amount of each part needed. Because there are seven parts, the total required volume is divided by seven. If 1400 ml of paint is required, the volume of each part will then be 200 ml. The volume of each component, in this example, would be 800 ml (4 x 200 ml) of surfacer, 400 ml (2 x 200 ml) of reducer, and 200 ml (1 x 200 ml) of hardener. A mixing cup or graduated beaker can be used to measure these volumes.

Part reduction can also be performed using a paint mixing stick. To use the type of stick shown in **Figure 26-22**, first choose the container in which you will reduce the paint. The sides of the cup must be straight. Tapered sides will cause inaccurate readings on the mixing stick. The size of the container will determine the size of each part of the mixture.

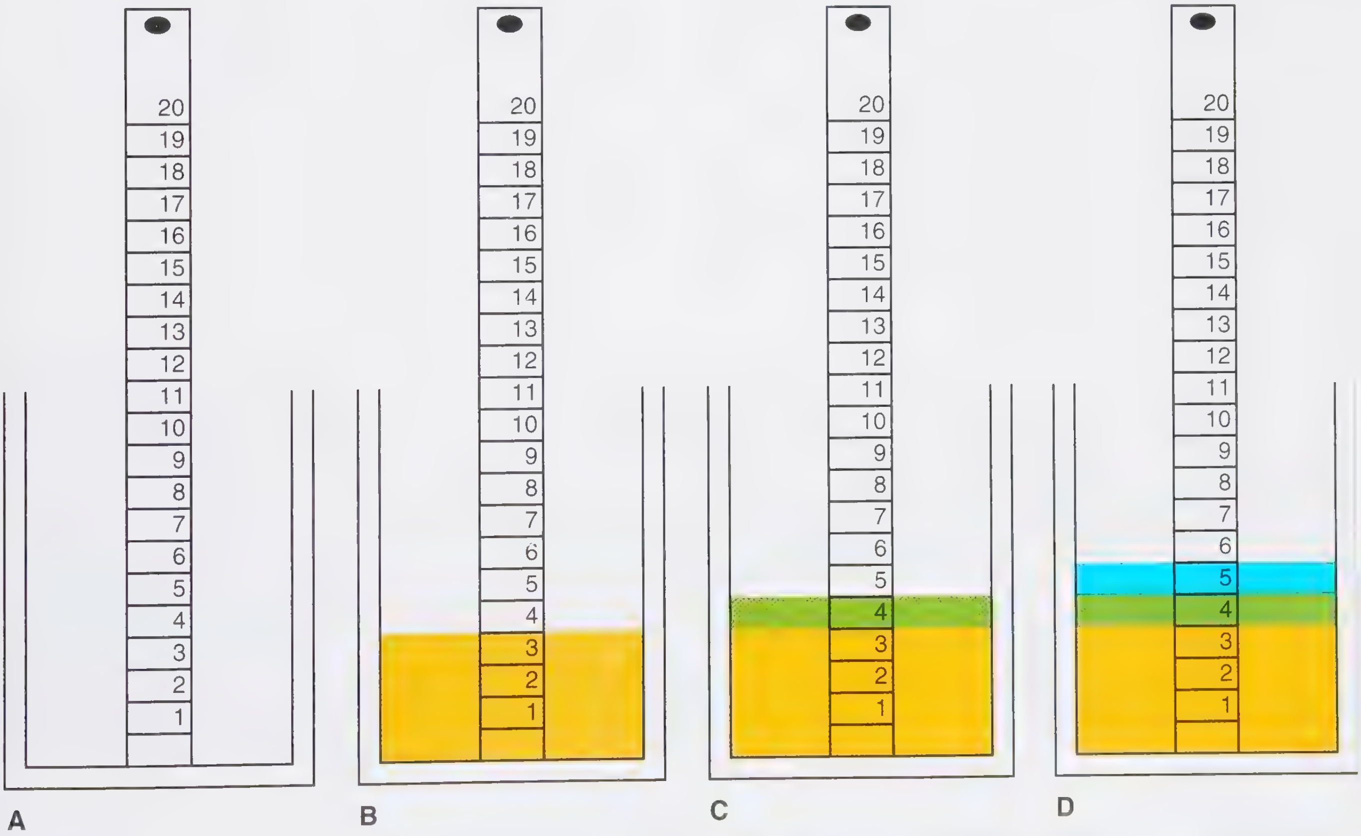


Figure 26-22. *A—This mixing stick is marked off in equal increments. The mixing ratio is 4:1:1. B—The 4 part is added to the 4. C—The first 1 part is added to the 5. D—The second 1 part is added to the 6.*

Place the stick in the container to decide on how much reduced paint is needed. Each graduation is a part. If the ratio is 4 parts primer, 1 part reducer, and 1 part hardener, add the primer up to the number 4, the reducer up to the number 5, and the hardener up to the number 6. If a smaller amount of reduced paint is required, for example up to the number 3 on the stick, this stick can still be used. For the 4:1:1 ratio, add the primer up to the number 2, then the reducer up to the 2 1/2 and the hardener up to the number 3.

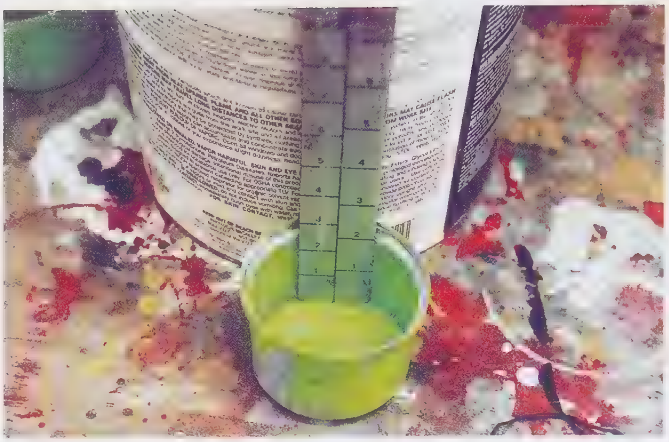


Figure 26-23. *When a small amount of reduced paint is required, use a small container.*

A dedicated paint mixing stick is made for a specific ratio. Again, choose a container in which to mix the reduced paint. The size of the container will determine the volume of the part and the amount of reduced paint produced. When only a small amount of reduced paint is required, use a small can. For example, when a small amount of surfacer is needed, the cap from a can of hardener can be used, **Figure 26-23**. Place the mixing stick in the can. Some technicians use a clothespin to hold the mixing stick steady. Decide on the amount of reduced paint needed by looking at the height of the numbers along the right edge of the mixing stick. Follow that number through the sequence. For example, if it is decided that the number 3 will give the proper amount of reduced paint, then add the first component to the first 3, the second component to the second 3, and the third component to the last 3. See **Figure 26-24**.

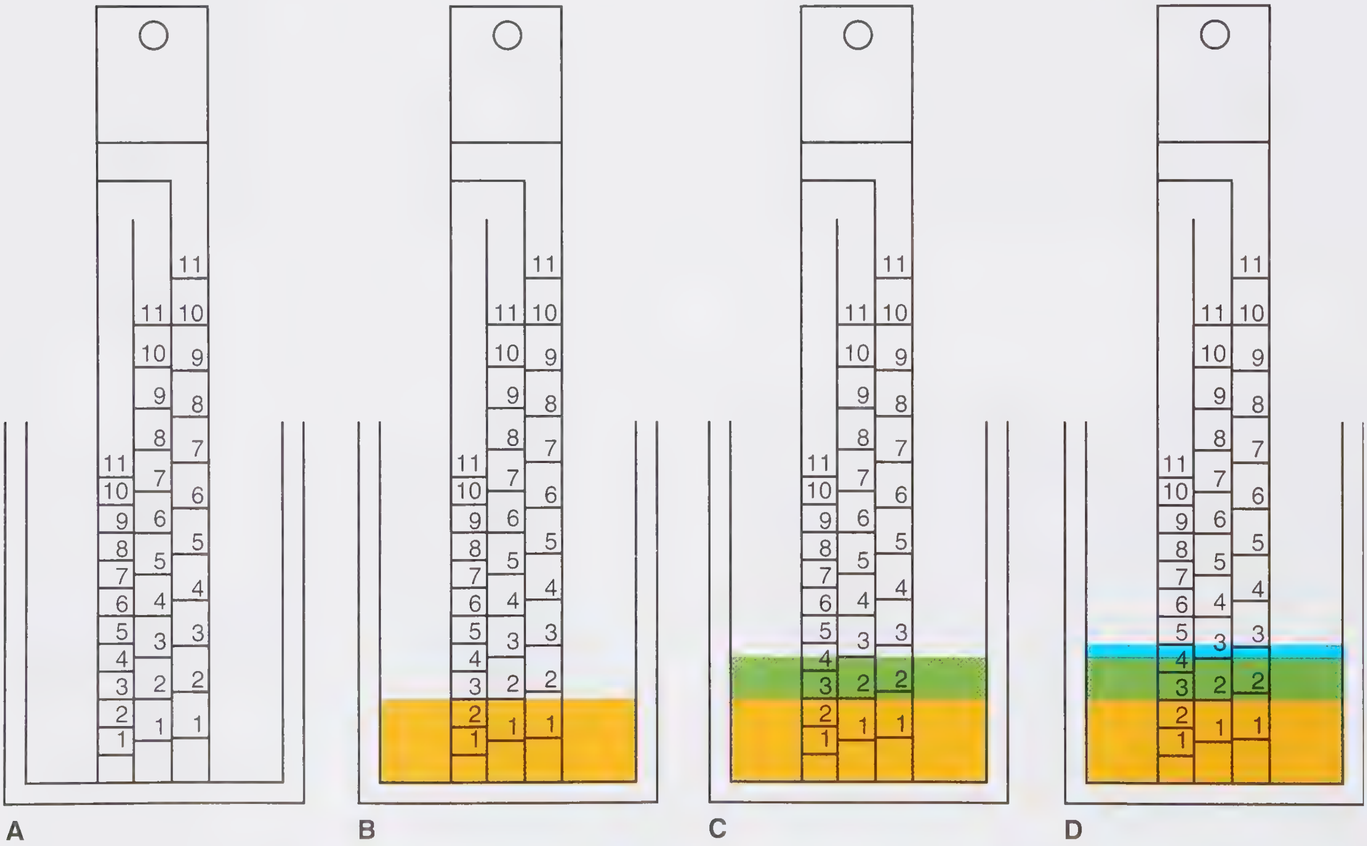


Figure 26-24. *A—A dedicated paint mixing stick will be used to add the proper amount of each component. Use a straight sided container. B—Add the first component to the left-hand three. C—Add the second component to the middle three. D—Add the last component to the right-hand three.*

If a mixing stick is not available, one can easily be made by marking ***graduations*** on a paint stick. Use a ruler to mark equal units on a paint stick. Each one of these units is a part. **Figure 26-25** shows what a self-made mixing stick looks like.

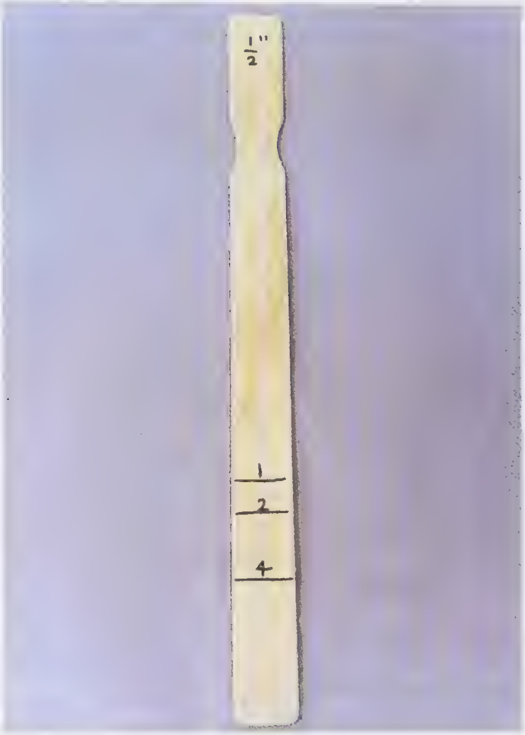


Figure 26-25. *This wooden paint stick has been measured in one-half inch increments to produce a 4:2:1 ratio. The four portion is 2 inches long, the two portion is 1 inch long, and the one portion is 1/2 inch long.*

Mixing cups can be used instead of mixing sticks. Mixing cups can be single-use; used to mix paint once, and then thrown away. Single-use mixing cups save cleanup time, which in a body shop is wasted, non-productive time. **Figure 26-26** shows one style of mixing cup. The mixing cup is marked in equal increments. The mixing ratio is 8:4:1, the first component is added to the 8, the next to the 12, and the last to the 13.

On another style of mixing cup, the increments are in the same ratio as the mixing ratio. See **Figure 26-27**. Pick one amount of paint you want to mix and add the components to the same number. The mixing ratio for this clear coat is 4:1. There is no 4:1 ratio on this cup so

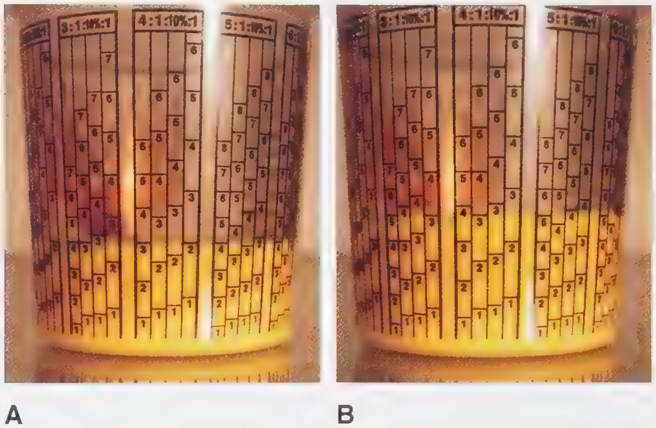


Figure 26-27. *The required mixing ratio is 4:1, but a 4:1 ratio is not available on this cup. Instead, the 4:1:10%:1 column is used but only the first two portions (4 and 1) are added. A—The first component has been added to the left 3. B—The second component has been added to the middle 3 to achieve the 4:1 ratio.*

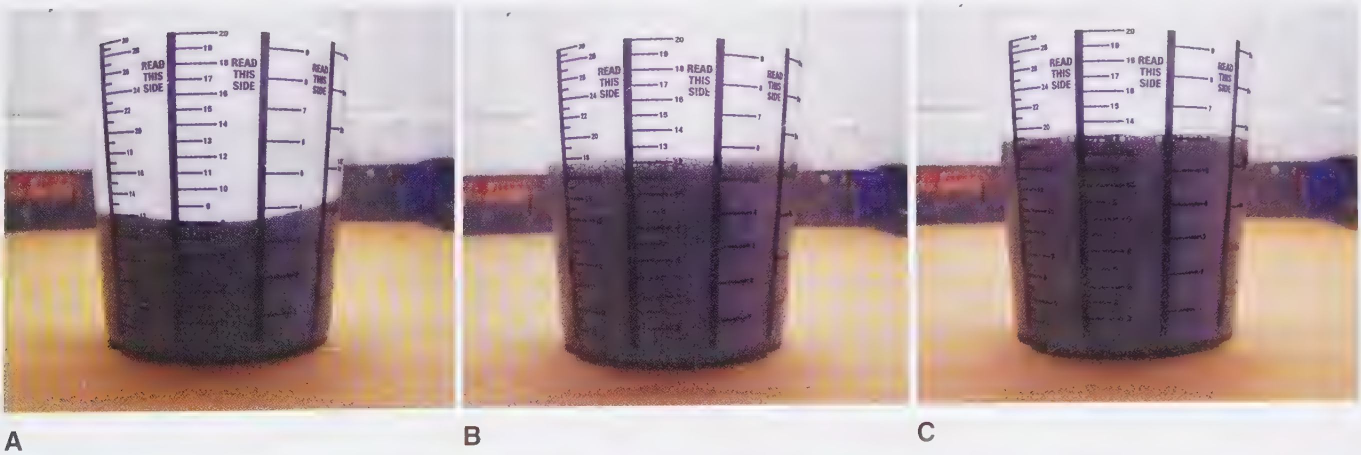


Figure 26-26. *A—The mixing ratio is 8:4:1. The first component is added to the 8. B—The second component is added to the 12. (Eight plus the 4 component = 12). C—The last component is added to the 13. (Twelve plus the 1 component = 13).*

the 4:1:10%:1 ratio is chosen and only the 4:1 portion is used. The first component is added to the first 3 and the second component is added to the second 3.

In yet another type of volume part reduction, one fluid ounce of hardener is added to one sprayable quart of basecoat. In this example, one pint of basecoat is combined with one pint of reducer to the proper viscosity, then one ounce of hardener is added.

Percent Reduction

Another way to reduce paint is by percentage. In percentage reduction, the amount of reducer is calculated as a percentage of the total amount of paint. Some reduction instructions may call for a 100% reduction. This means that if there is 1 pint of paint, 1 pint of reducer is needed. A 50% reduction means that if there is 1 pint of paint, a 1/2 pint of reducer is needed. A 200% reduction means that if there is 1 pint of paint, 2 pints of reducer are added.

Waterborne basecoat is often reduced by percent volume. One type of waterborne basecoat is reduced 20–30% for metallics or pearls and 10% for solid colors with a special aqua-based thinner. If a hardener is used in the basecoat, the hardener is added and the viscosity is checked. If the viscosity is not in the desired range (23–28 seconds), additional aqua-based thinner is added to dilute the basecoat. Another brand of waterborne basecoat is also reduced by percent volume. With this type of paint, the temperature inside the spray booth determines the amount of reducer added to the basecoat. If the temperature is below 90°F (32°C), the reduction is 10%. If the temperature is above 90°F, the reduction is 20%.

Combination Volume Reduction

Some types of paints are reduced by parts *and* percentages. **Figure 26-28** shows a paint stick that is marked in parts and percentages. The paint is mixed by parts first, usually two parts. Then the third component is added as a percentage of the total of the first two parts. For example, a basecoat and basecoat reducer can be added in a 1:1 ratio to make one pint of reduced basecoat. Then 10% of one pint of hardener is added to the reduced basecoat. Another type of basecoat requires a different approach. The required amount of basecoat is weighed on a scale, and hardener is added to increase the weight of the basecoat by 10%. Then the mixture of basecoat and hardener is reduced 75–100% by volume with the addition of basecoat reducer.

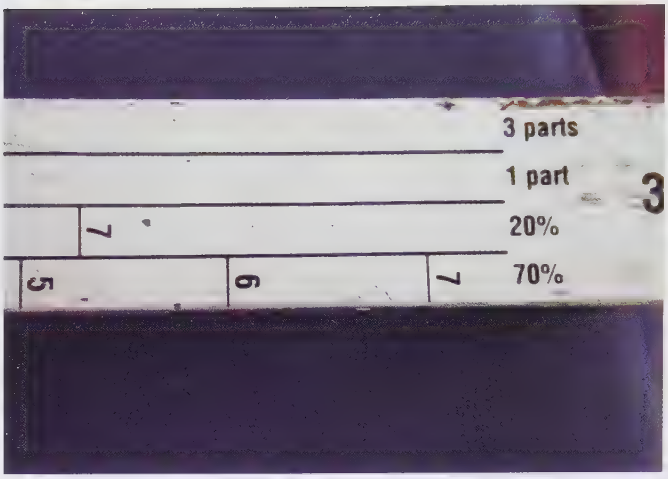


Figure 26-28. *The mixing ratio on this stick is 3:1 plus a 20% or 70% reduction.*

Weight Reduction

Another way to reduce paint is by weight. Because the various components of reduced paint—paint, reducer, and hardener—do not weigh the same amount, the volume reduction ratios cannot be used in weight reduction. **Figure 26-29** shows a chart of weight reduction. To reduce paint by weight, decide how much paint is needed and place the can on the scale. Zero the scale and follow the chart. Add the proper weight of each component. **Figure 26-30** shows the weight reduction of a sealer.

After the paint is reduced, it must be stirred. Stirring will thoroughly combine the paint, reducer, and hardener. Always stir paint after reducing. See **Figure 26-31**.

Sprayable Surfacer Cumulative Formula (one pint)
378.5g surfacer
458.0g hardener
591.8g reducer

Figure 26-29. *One pint of sprayable surfacer is mixed by weight following this cumulative formula.*

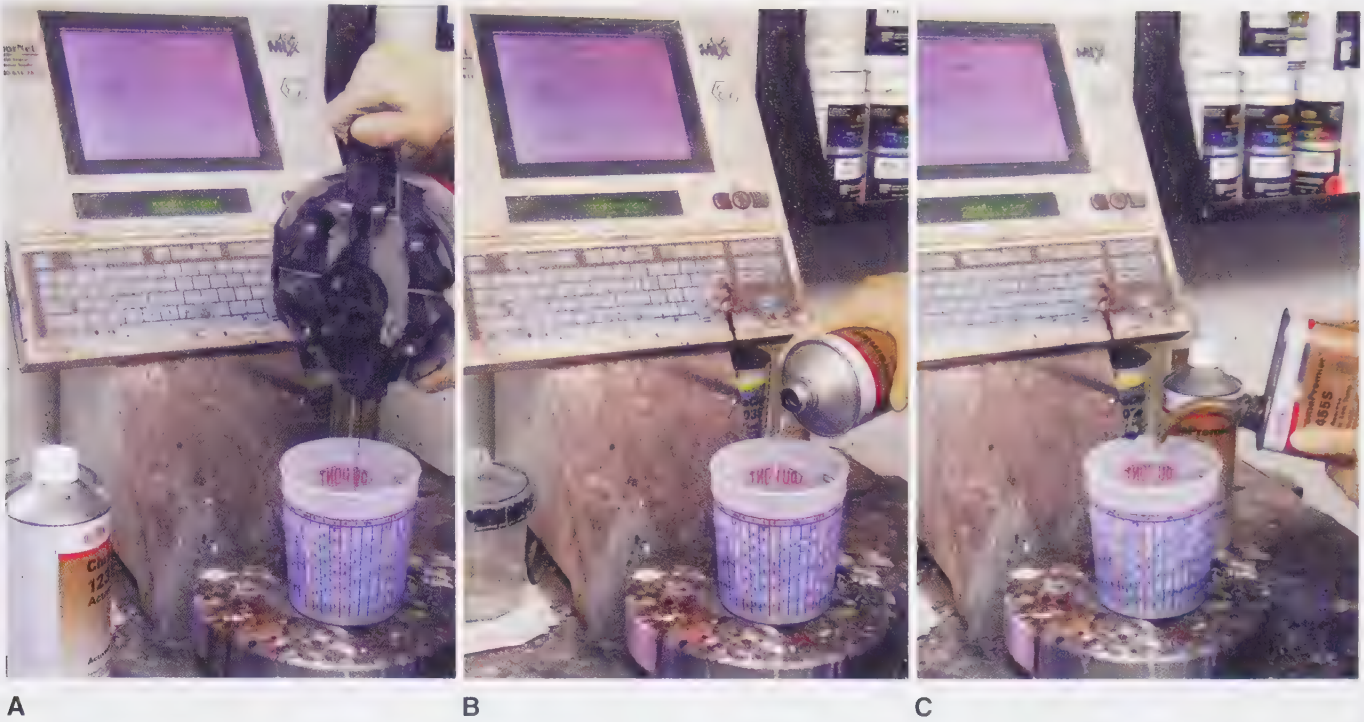


Figure 26-30. *A—This sealer is mixed by weight. The first component is added from a gallon can to a cup that is sitting on a scale. B—The activator is added next. Some paint manufacturers call the hardener an activator. C—The reducer is added last.*

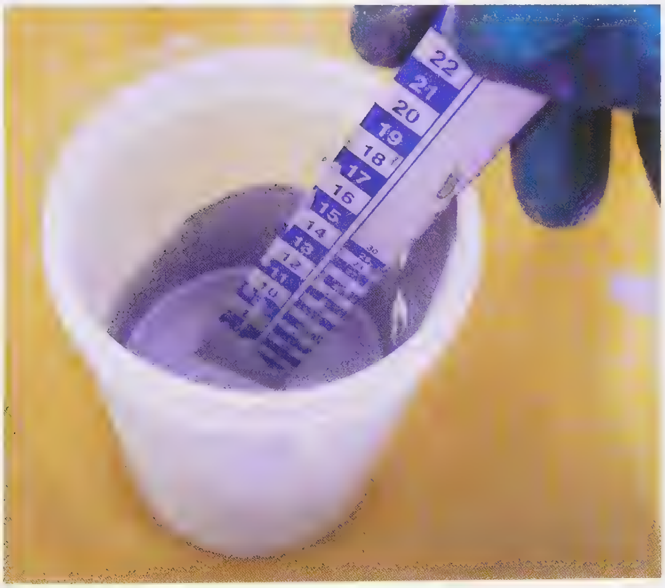


Figure 26-31. *The mixing stick can be used to thoroughly mix the paint components.*

Summary

- Paint colors are mixed by adding the specified amounts of various tints.
- Each vehicle has a paint code indicating the color of the paint.
- Each paint manufacturer has a unique paint part number for each color.
- Intermix colors are made using tints, a digital scale, a mixing bank, mixing lids, and a can.
- Some manufacturers make tints containing binder. Other manufacturers require that binder be added separately.
- A paint formula lists all of the tints needed to make a color.
- Most large body shops have their own paint mixing systems.
- Paint mixing equipment includes a scale, mixing bank, mixing lid, paint, and a shaker.
- An overpour occurs when more than the required amount of tint is added.
- An overpour can be corrected.
- Viscosity is the measurement of the thickness of paint.

- Paint can be reduced by volume or by weight.
- Reducer must be matched to the spray booth temperature.
- Paint and tints must always be thoroughly stirred before mixing and reducing.

Review Questions

Please do not write in this textbook. Place your answer on a separate sheet of paper.

1. Explain how to measure viscosity with a viscosity cup.
2. The ______ is a list of tints used to make a color.
3. Paint codes for all vehicles are found inside the driver's door. True or False?
4. Paint part numbers can be found in a ______.
5. A(n) ______ color was mixed by the paint manufacturer.
6. Some body shops do not have an in-house paint mixing system, so they rely on a supplier called a jobber. True or False?
7. After an empty paint can is placed on a digital scale, the scale must be ______.
8. A nickel weighs ______ grams.
9. Before tints are ready for use, they should be stirred for a minimum of ______ minutes.
10. Pearl tint can be supplied as a powder. True or False?
11. Metallic flakes are available in coarse, medium, and fine sizes. True or False?
12. A comprehensive tint requires that a separate binder be added to the mixture. True or False?
13. A(n) ______ is used to orientate metallic flakes after the paint is sprayed.
14. A quantitative formula lists the amount of each tint required. True or False?
15. When mixing paint, tints should be added slowly and poured into the ______ of the mixing container.
16. Paint colors mixed in a body shop do not need a label. True or False?
17. ______ is an indication of paint's liquid thickness, and is measured with a special cup.
18. A 150% reduction is required. How much reducer is added to one quart of paint?
19. Explain how to reduce paint by weight.
20. Waterborne paint must be stirred on a paint shaker before use. True or False?

ASE-Type Questions

1. Paint code location is being discussed. Technician A says that the paint code for a Ford vehicle is found inside the passenger's door. Technician B says that the paint code for all GM vehicles is found in the glove compartment. Who is right?
   (A) A only.
   (B) B only.
   (C) Both A and B.
   (D) Neither A nor B.
2. All of the following can be used to find a paint part number EXCEPT:
   (A) a color chip book.
   (B) a refinish manual.
   (C) a paint code book.
   (D) a computer loaded with a paint code CD.
3. Technician A says that a factory pack color always matches the vehicle. Technician B says that a factory pack color may not match the vehicle. Who is right?
   (A) A only.
   (B) B only.
   (C) Both A and B.
   (D) Neither A nor B.
4. Jobber-mixed paint is also called ______.
   (A) intermix paint
   (B) factory pack paint
   (C) tint
   (D) solvent
5. Technician A says that the calibration of a digital scale can be checked with a nickel. Technician B says that a penny should be used to check a digital scale. Who is right?
   (A) A only.
   (B) B only.
   (C) Both A and B.
   (D) Neither A nor B.
6. The type of tint that has binder as part of the tint is called ______.
   (A) metallic tint
   (B) pearl tint
   (C) single tint
   (D) comprehensive tint
7. Which of the following tints is used to increase mixing accuracy?
   (A) Metallic tint.
   (B) Pearl tint.
   (C) Low-strength tint.
   (D) High-strength tint.

8. Which of the following terms means that too much of one tint is added to the mixture?
   (A) Viscosity.
   (B) Overpour.
   (C) Thick.
   (D) Thin.
9. All of the following are examples of a 1:1 reduction EXCEPT:
   (A) 1 quart paint, 1 quart reducer.
   (B) 1 quart paint, 1 pint reducer.
   (C) 1 quart paint, 2 pints reducer.
   (D) 200 ml paint, 200 ml reducer.
10. A paint mixing stick will be used to reduce paint. Technician A says to use a straight-sided cup. Technician B says to use a taper-sided cup. Who is right?
    (A) A only.
    (B) B only.
    (C) Both A and B.
    (D) Neither A nor B.
11. Paint is to be reduced by weight. Technician A wants to follow the volume ratio 4:2:1. Technician B says that the volume ratio will not work for weight reduction. Who is right?
    (A) A only.
    (B) B only.
    (C) Both A and B.
    (D) Neither A nor B.
12. The mixing ratio is 6:2:2. Fifty ounces of paint is needed. What is the size of the part?
    (A) 5 oz
    (B) 10 oz
    (C) 15 oz
    (D) 20 oz
13. A two-part paint has a viscosity measurement of 24 seconds. A sprayable viscosity of twenty seconds is needed. Technician A wants to add reducer. Technician B wants to add paint. Who is right?
    (A) A only.
    (B) B only.
    (C) Both A and B.
    (D) Neither A nor B.
14. A three-part paint has a viscosity measurement of 16 seconds. A sprayable viscosity of 20 seconds is needed. Technician A wants to add reducer. Technician B wants to add paint. Who is right?
    (A) A only.
    (B) B only.
    (C) Both A and B.
    (D) Neither A nor B.
15. A graduated stick is used to reduce paint. The mixing ratio is 4:1:1. Each graduation is one part. The last graduation used will be ______.
    (A) 6
    (B) 7
    (C) 8
    (D) 9

According to author Mike Crandell, most painters do not know how to correctly set up a spray gun. Study the following chapter until you understand how to set up a spray gun for pattern size and shape, material, and air pressure. (Shutterstock)

Chapter 27

Spray Technique

Objectives

After studying this chapter, you will be able to:

- Describe the basic skills needed to spray paint. These skills include hand/eye coordination, flexibility, rhythm, and the ability to detect and correct flaws while painting.
- Understand how to set up a spray gun for spray pattern size, material, and air pressure.
- List the spray gun handling variables including: body position, fan orientation, distance, speed, overlap, and triggering.
- Describe the types of coats used when painting panels.
- Demonstrate the procedures for spraying various types of panels.
- Explain how to walk the side of a vehicle.

Technical Terms

air pressure control knob
arcing
banding
body position
complete paint job
fan knob
flood test
flow out
fluid control knob
heeling
internal flow out
mottling
overlap
pattern control knob
pattern test
spray technique
stroke
travel speed
triggering
walking the panel
wet coat

Introduction

This chapter explains how to use a spray gun. A spray gun uses air pressure to break liquid paint into a mist of tiny droplets. This process is known as atomization. The mist, or fan, is then sprayed onto the surface being painted. The painter is responsible for the setup and operation of the spray gun. The operation of the spray gun is known as spray technique. ***Spray technique*** requires the balancing of several variables. One of the variables is speed. The spray gun must be moved at the proper speed across the panel being painted. Another variable is distance. The spray gun must be held the proper distance from the panel. Successful spray painting balances these two key variables, as well as others, to produce a smooth paint job.

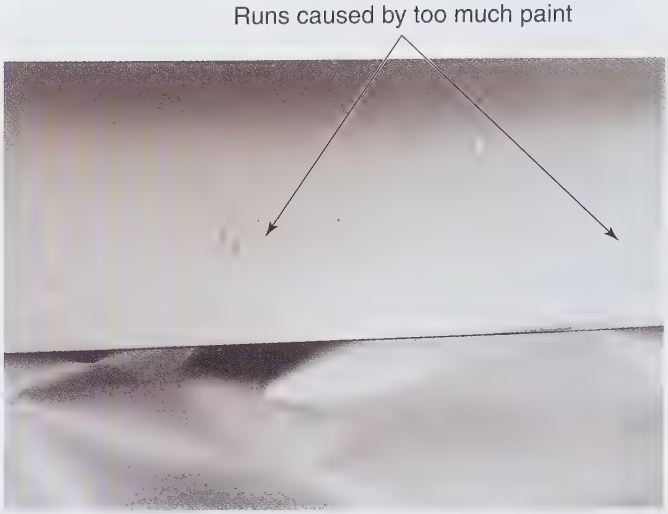


Figure 27-1. *Too much paint was applied to this panel. A run was caused by flow out of excess paint.*

Paint Characteristics

Liquid paint is atomized by a spray gun. The different types of paints used in the typical collision repair shop, such as primers, basecoats, and clearcoats, will have different viscosities. These paints must be properly reduced to acceptable viscosity levels for good atomization. Successful atomization requires properly reduced paint and the correct diameter fluid tip. Spray gun fluid tip selection is based on the viscosity of the paint, as explained in Chapter 25.

Different types of paint may have different drying characteristics. One of the most important drying characteristics is flow out. ***Flow out*** is the tendency of the wet paint to level and smooth out after spraying. On a vertical surface, such as the door of a vehicle, gravity pulls the paint down, causing the paint surface to flow out. However, if too much paint is sprayed on a vertical surface, the downward force of gravity on the extra paint forms a run. See **Figure 27-1**. When painting a vertical surface, the technician must pay attention to areas where runs are likely. Places where the body flares and areas where the adjacent panels are perpendicular to each other are danger areas where the potential for runs is high.

The technician's spray technique can also cause runs. Moving too slow, spraying too close, excessive overlap, and improper triggering are the most common causes. Runs are a problem on vertical surfaces because of the downward force of gravity. On flat, horizontal surfaces gravity does not pull down on the paint, so runs are usually not a problem.

On a horizontal surface, paint may look rough if the painter does not apply a ***wet coat***. A wet coat contains more paint and stays liquid long enough to level out. Because gravity does not level the wet paint on a horizontal surface, the paint must stay wet long enough for internal flow out. ***Internal flow out*** means the wet paint will continue to level and smooth out until it dries. The wetter the paint, the longer the leveling time.

On a vertical surface, apply paint slightly drier to prevent runs. On a horizontal surface, apply the paint slightly wetter for improved internal flow out.

Adjustments

There are three possible adjustments on spray guns: spray fan size and shape, material flow, and air pressure. See **Figure 27-2**. Additionally, pressure pot pressure can be adjusted on a pressure-feed spray gun. These adjustments are set to deliver the right amount of paint in a spray fan of the correct size and shape. The size of the area to be painted and the type of the paint determine what these adjustments will be.

The ***fan knob***, also called the ***pattern control knob***, regulates the amount of air that flows through the air horns. It controls the shape and size of the spray pattern. Turning the ***fluid control knob*** adjusts amount of paint or material that is introduced into the airstream. As the fluid control knob is turned out (counterclockwise), the trigger can move the needle further and further out from the hole in the fluid tip. Set the fluid control knob to fill the fan with paint. A small fan requires less paint; a large fan requires more paint.

To set the fluid adjustment knob, turn the knob all the way in. Hang a piece of masking paper on the spray booth wall, hold the gun 6"–8" away and trigger the spray gun for a second. Almost nothing should come out of the nozzle. Turn the fluid control knob out one full turn and repeat the test procedure. Keep turning the fluid control knob out, a half turn at a time, until you get a full pattern.

When set below the maximum adjustment, the setting of the fluid adjustment knob will allow less than the maximum amount of paint to mix with the air. This is important for atomization. Orange peel, an undesirable textured, dimpled surface, results when air pressure cannot break the paint into small droplets. If too much paint and not enough air are discharged from the spray gun, atomization is poor and orange peel is the result. If orange peel is present, the fluid adjustment knob can be turned in to decrease the amount of paint. This will change the ratio of paint to air, improving atomization.

The ***air pressure control knob*** is used to adjust air pressure. Adjusting air pressure is as important as setting the fluid controls. Insufficient air pressure leads to poor atomization, which causes orange peel. Too much air pressure blasts paint out of the spray gun, causing excessive overspray and a dry, rough finish. Also, the size of the fan is determined by air pressure.

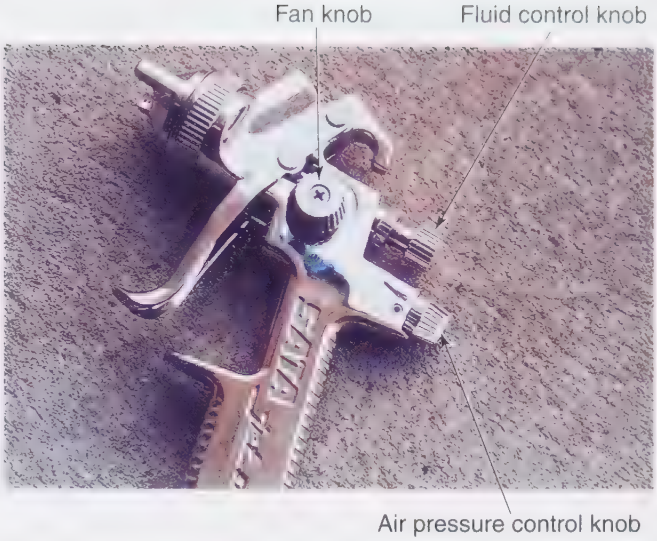


Figure 27-2. *The fan knob, fluid control knob, and air pressure control knob are turned in or out to adjust this gravity feed spray gun.*

Spray Gun Setup

A properly adjusted spray gun will apply a smooth coat of paint. As previously mentioned, there are three adjustments on a spray gun: fan size, material flow, and air pressure. Spray gun setup is a balance of these three adjustments, with a separate knob controlling each one. The paint manufacturer or spray gun manufacturer will specify the air pressure setting. The other two adjustments, fan size and material flow, must be determined and set by the technician. An improperly adjusted spray gun will still apply paint, but the results will be less than satisfactory. Also, the spray gun should be clean before attempting setup.

There are many ways to set up a spray gun, but it is important to remember that all of the adjustments are interrelated. Changing one will have an effect on the other two. Methods for setting up both conventional and HVLP spray guns are discussed in the following sections. Keep in mind that the methods presented are not the only ways to set up a spray gun.

Setting up a Conventional Spray Gun

Set the fan first. Fill the cup with paint and connect the spray gun to an air hose supplying approximately 40 psi of air. Set the shape of the fan based on the size of the area to be sprayed. See **Figure 27-3**. When the fan knob is turned all the way out, the maximum amount of air hits the spray mist, making a narrow (7"–9" tall), oval-shaped fan. As the knob is turned in, the amount of air delivered to the air horns decreases, changing the shape of the fan from an oval shape to a 2"-diameter round pattern.

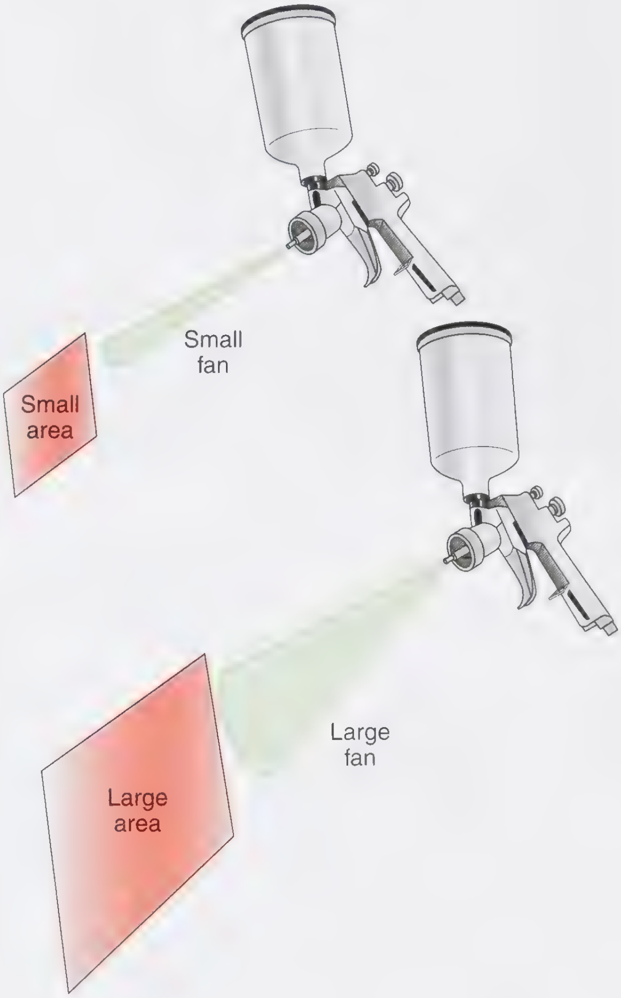


Figure 27-3. *Spray a small area with a small fan; spray a large area with a large fan.*

When painting a large area, such as a hood, the fan adjustment should be set to make the tall, oval-shaped fan. This will cover the surface with the minimum number of passes. When painting a small area, such as the inside of a doorjamb, the spray gun should be set to a small circle. This will paint the small area with the minimum amount of overspray.

After setting the fan, the fluid control knob should be adjusted to the appropriate setting. The fluid control knob is used to adjust the distance the needle moves away from the hole in the fluid tip when the trigger is pulled. Trigger movement, beyond the stop for the air valve, is adjusted by the fluid control knob. Turning the fluid control knob all the way in (clockwise) prevents the trigger from moving the needle back and exposing the hole in the fluid tip. Turning the knob out (counterclockwise) allows the trigger to move the needle out of the fluid tip hole and release paint into the compressed airstream. When the trigger moves back far enough to touch the body of the spray gun, material flow is at the maximum. Some technicians turn the fluid control knob all the way in and then count the number of turns out. This gives them an idea of what the material setting is. If the fan is set at maximum, then the material flow should also be set at maximum. The material should fill the fan. If the fan is set at less than maximum, the material flow should be decreased accordingly.

After adjusting the fan and material settings, the air pressure must be set. As previously stated, air pressure recommendations are provided by the paint or spray gun manufacturer. See **Figure 27-4**. The best way to set up air pressure is not at the gun, but at the regulator. A regulator has a diaphragm that adjusts the air pressure with no loss in air volume, while a valve sets air pressure by restricting air volume. Set the air pressure control knob on the spray gun to maximum and use the regulator and gauge on the spray booth wall to set air pressure. The air pressure should be set with the spray gun trigger pulled all the way back. With air flowing out of the spray gun, the regulator is set to the desired air pressure. The air pressure supplied to the spray gun will be the pressure that is discharged. **Figure 27-5** shows a technician setting the air pressure at the regulator. In this example, a short length of hose is used. A hose that is less than 30' long with an interior diameter of 5/16" and with one quick-disconnect fitting at the spray gun, helps minimize the air pressure drop in the hose between the regulator and the spray gun. An inline air pressure gauge is used to check the air pressure at the spray gun air inlet. See **Figure 27-6**.

Setting up an HVLP Spray Gun

An HVLP spray gun is set up in much the same way as a conventional spray gun. In fact, the first two adjustments are the same. The air pressure setting, however, is different.

Spray Gun Types and Recommended Air Pressure

Spray Gun Type	SATA JET 90/SL & RP	SATA JET/B	SATA JET/H	SATA JET/K
Basecoat ChromaBase® ChromaPremier™ Chrommax WBC™	40–50 psi	45–55 psi	50–60 psi	65 psi
Clearcoat 1780S Iso-Free <<4500 and 4700>> V7500S ChromaClear® Multi-use 7600S ChromaClear® Super Productive V7600SChromaClear® Super Productive	40–50 psi	45–55 psi	50–50-psi	65 psi
Clearcoat 3500s ChromaClear® High Solids 7800S ChromaClear® High Glamour Urethane ChromaPremier™ Productive Clearcoat ChromaPremier™ Appearance Clearcoat	40–50 psi	45–55 psi	50–60 psi	65 psi

Figure 27-4. *This chart gives one manufacturer's air pressure recommendations for various spray gun types and paint products. (SATA USA)*

There are two ways to set air pressure on an HVLP spray gun. The conventional way is to first check the maximum inlet air pressure. HVLP spray guns have a maximum inlet air pressure setting engraved into the body of the spray gun. See **Figure 27-7**. If the indicated maximum inlet air pressure is supplied to an HVLP spray gun, the maximum discharge air pressure for the HVLP spray gun (10 psi) will be discharged. This is a less precise method of setting pressure because pressure below 10 psi can only be estimated. If more than the specified maximum inlet pressure is supplied to an HVLP spray gun, the discharge pressure will be greater than 10 psi. At a discharge pressure greater than 10 psi, the HVLP spray gun will no longer function as intended.

The other method of setting air pressure on an HVLP spray gun involves the use of a special gauge assembly to measure the discharge air pressure. See **Figure 27-8**. The gauge assembly is installed

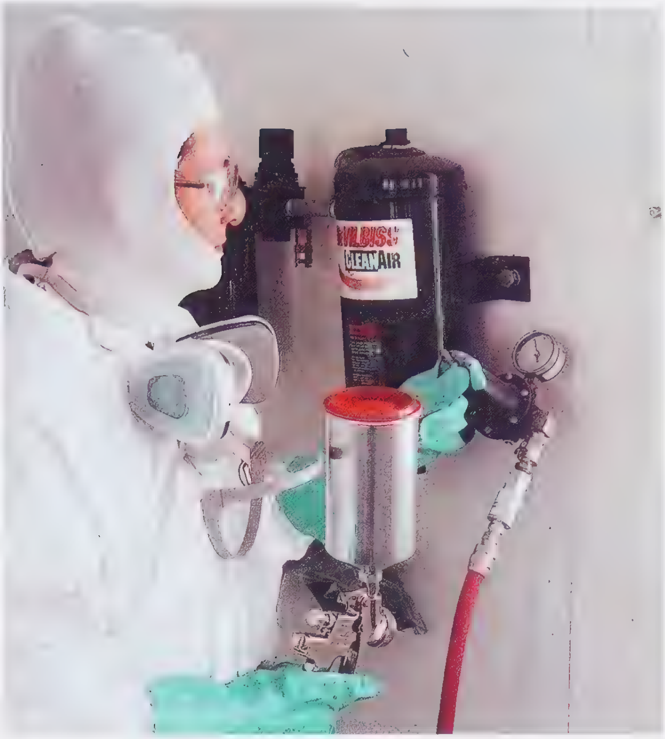


Figure 27-5. *Set the air pressure at the regulator on the spray booth wall with air flowing through the spray gun.*

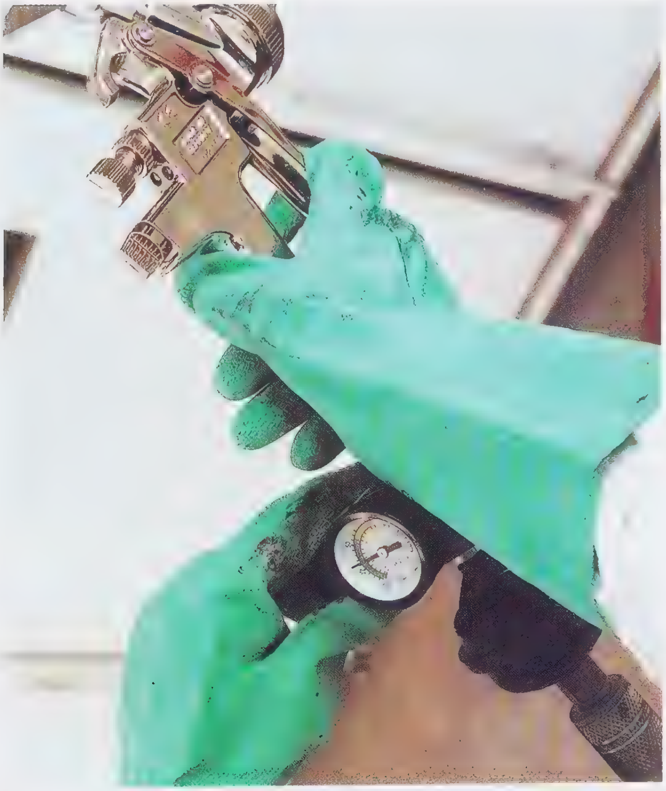


Figure 27-6. *The air gauge is attached to the spray gun. The pressure at the inlet of the spray gun is indicated on the gauge. Adjust the spray gun's air pressure with a regulator.*

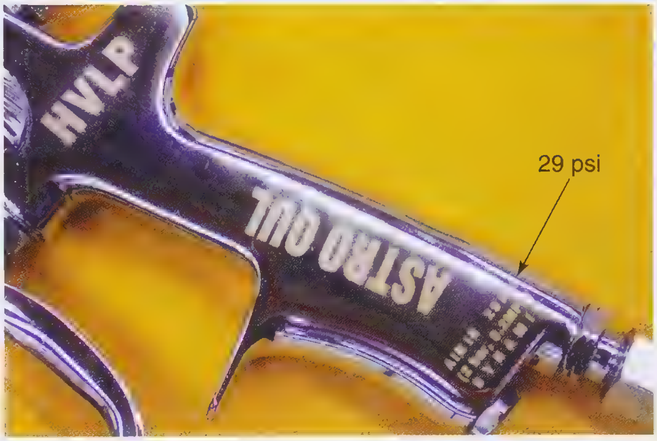


Figure 27-7. *The air pressure indicated, 29 psi, at the inlet will make an air cap discharge pressure of 10 psi.*

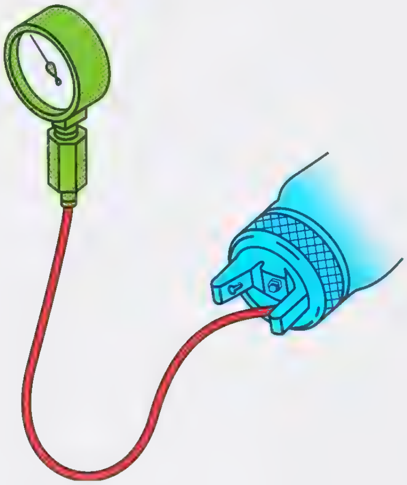


Figure 27-8. *This device measures and displays the discharge air pressure. (DeVilbiss)*

on the spray gun in place of the normal air cap. The discharge air pressure is set to 10 psi by adjusting the air regulator while air is streaming through the spray gun. Once the desired air pressure is set, the special gauge assembly is removed and the normal air cap is installed. After initial adjustment, the technician can reduce air pressure at the regulator if needed. However, the air pressure should not be increased because this will cause more than 10 psi to be discharged. This special gauge assembly allows the spray gun to be set accurately at pressures below 10 psi.

Balancing the Spray Gun

Changing one of the spray gun adjustments will affect the other two. For example, increasing the fan size will decrease the air pressure and spread the paint over a larger area, making a drier spray. Pressure is force divided by area.

When one adjustment is made, slight changes may be needed in the other adjustments to achieve the proper balance. For example, if air pressure is turned up to the recommended value after the fan and material are set, the size of the fan may increase. Conversely, if the air pressure is turned down after the fan and material are set, the fan may decrease in size. In either case, tune the fan and air pressure knobs to get the right size fan at the right air pressure. Also, check the material setting after making these adjustments. **Figure 27-9** summarizes the relationship of these adjustments.

Pattern Test

As outlined in the previous sections, the spray gun must be set up correctly if it is to apply paint as efficiently as possible. A ***pattern test*** is performed to fine tune spray gun adjustments. Mask off a 36" x 36" area on the side of the spray booth with masking paper. Load the spray gun with paint and set up the spray gun by adjusting fan, material, and air pressure. Hold the spray gun the same distance from the masking paper as the height of the fan. If the spray gun produces a 9" tall oval fan, hold the gun so the air cap is 9" away from the masking paper. To test a gun set to a 7" tall fan, hold the gun 7" away from the masking paper. In one smooth motion, pull the trigger all the way back and immediately release it. Look at the paint pattern. The pattern should be a narrow (1 1/4" wide) oval with the pattern thinning at the top and bottom of the oval. The thinning pattern is due to the smaller number and size of atomized paint droplets in these areas. If there is a run in the middle of the pattern, turn the fluid adjustment in to decrease the amount of paint. See **Figure 27-10**. Hold the spray gun at the proper distance and try again. When the runs have been eliminated, turn your attention to the top and bottom of the pattern. Adjust the fluid control knob to make the droplets at the top and bottom of the pattern as small as possible without making the pattern too faint.

Spray Gun Adjustment – Cause and Effect		
Adjustment at Gun	**Effect on Spray Gun**	**Effect on Paint**
Increase air pressure	Increase fan size Decrease material	Drier spray
Decrease air pressure	Decrease fan size Increase material	Wetter spray
Increase fan size	Decrease air pressure Decrease material	Drier spray
Decrease fan size	Increase air pressure Increase material	Wetter spray
Increase material	No effect on fan size No effect on air pressure	Wetter spray
Decrease material	No effect on fan size No effect on air pressure	Drier spray

Figure 27-9. *Changing one of the spray gun adjustments will affect the other two. This table summarizes how adjustments influence each other and how they affect paint.*

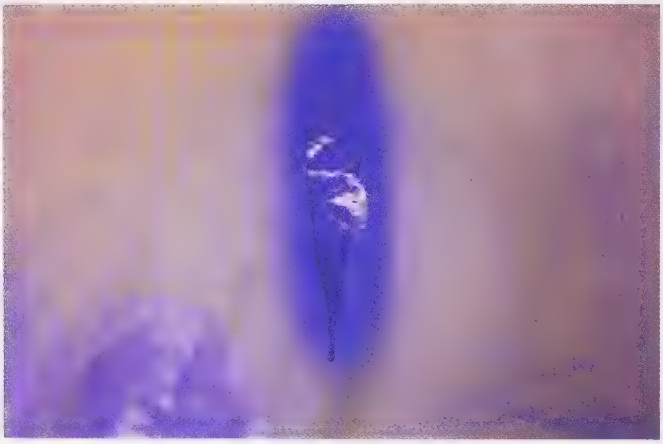


Figure 27-10. *This pattern test shows a run in the center caused by too much paint. Reduce the amount of material.*

Common problems that can be seen in the spray pattern are shown in **Figure 27-11**. These include:

- Sickle pattern—A clogged or partially blocked air horn will cause a sickle- or comma-shaped pattern. Clean out the air horn hole with a wooden toothpick.
- Hourglass pattern—In an hourglass pattern, the center is dry, and the top and bottom are wet. Likely causes are too much air pressure or not enough material. The solution is to decrease the air pressure or increase material flow.
- Wide pattern—There is not enough air pressure or too much material. Increase the air pressure and/or reduce the material.
- Split pattern—Blockage in the air cap or fluid tip. Clean the air cap by removing and soaking it in thinner. Clean air cap holes with a wooden toothpick. Wipe the fluid tip with a rag soaked in thinner to remove dried paint.
- Spitting—Spitting means that the paint discharge is not consistent. The spray gun alternately discharges paint and then air. This is usually caused by a loose fluid tip. Tightening the fluid tip will correct the problem.
- Bubbling—Caused by atomized air inside the spray gun moving through paint passages. A loose fluid tip can cause the problem as well as a shrunken or damaged plastic gasket or O-ring.

Pattern Test

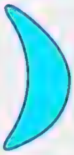
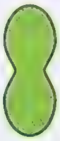
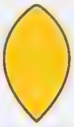
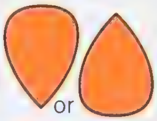
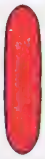
Name	Shape	Correction
Sickle		Clean air horn holes
Hourglass		Decrease air pressure or increase material
Wide		Increase air pressure or decrease material
Split		Clean air cap or fluid tip
Normal		No correction needed, good pattern

Figure 27-11. *A pattern test will show if the spray gun is adjusted correctly or if it needs cleaning.*

Flood Test

A ***flood test*** is a check of paint distribution within the spray pattern. A flood test is made on a sheet of masking paper taped to the spray booth wall. Turn the air cap so the air horns are oriented up-and-down rather than side-to-side. This will make the fan horizontal instead of vertical. Position the spray gun the same distance from the masking paper as the length of fan pattern.

Hold the spray gun stationary and fully pull the trigger back and hold it for 4 seconds. Four seconds is a long time, and paint will flood the spray pattern and run down the masking paper like a waterfall. If the runs are uniform from left to right, the paint distribution is correct. If, for example, there are heavy runs on one side of the spray pattern and fewer, lighter runs on the other side, then paint distribution is not uniform and the spray gun must be adjusted accordingly. See **Figure 27-12**.

An incorrectly adjusted spray gun cannot apply paint efficiently. No amount of spray gun technique can compensate for an improperly adjusted spray gun. Learn how to correctly set up the spray gun.

Flood Test

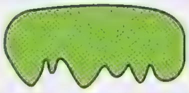
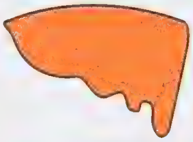
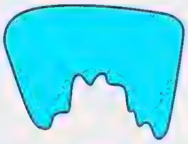
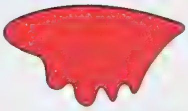
Name	Shape	Correction
Good, uniform runs		None
Heavy on one end		Clean air cap or fluid tip
Heavy on both ends		Decrease air pressure or increase material
Heavy center		Increase air pressure or decrease material

Figure 27-12. *A flood test also shows if the spray gun needs cleaning or adjustment.*

Basic Painting Skills

The paint technician should possess several basic qualities including eye/hand coordination, flexibility, and rhythm. The technician should also have the ability to observe the paint as it is being applied and correct any problems. With good spray technique, a uniform coat of paint will be applied to a surface.

While spraying, the paint technician must watch the paint as it is applied and keep an eye on the path ahead. Looking at the applied paint tells the technician if any changes are needed in technique. Looking at the path ahead allows the technician to anticipate changes in the surface. A change in the surface could be a body line or an area where the body flares out. The technician's eyes and hands must work together. When the technician's eye sees that a modification in technique is needed, the hand must be able to do it.

A paint technician must be able to stretch and squat when spraying. See **Figure 27-13**. This requires flexibility. Most of the muscles in the body will be used when spraying. An individual who can stretch to reach a panel will have a much easier time learning how to spray. A tall, long-armed painter will find spraying panels to be much easier than a shorter painter. There are ways for a short individual to compensate for insufficient reach. When spraying a vehicle roof, for example, a painter can stand on a bench. Flexibility can be improved with exercise.

The successful painter will move the gun along the surface at a constant distance and speed. In short, painting has a *rhythm*. Once the first ***stroke*** (one pass of the spray gun at a specific distance and speed) is made, all subsequent strokes should match the initial stroke. By doing this, a uniform amount of paint will be applied. Few painters come by this ability naturally; most develop this rhythm only through practice.

The technician must be observant when spraying and be prepared to act when a problem arises. This ability will be gained with experience. **Figure 27-14** lists some problems that may be encountered while spraying.

Spray Gun Handling

Spray gun handling can be broken down into six areas: body position, fan orientation, distance, speed, overlap, and triggering. Each of these areas will be discussed in detail in the following sections.

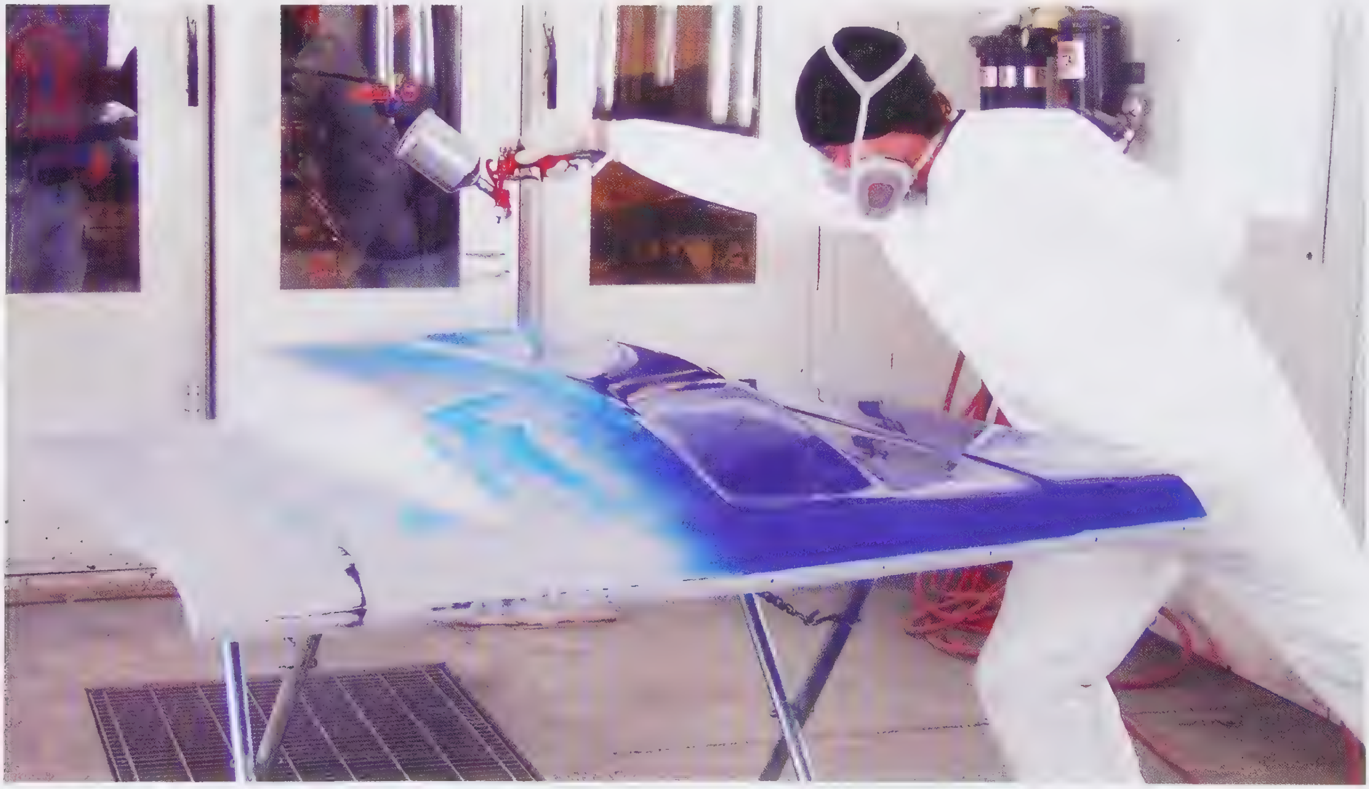


Figure 27-13. *Stretching is an essential part of spray technique.*

Common Spray Painting Problems and Solutions		
Problem	**Cause**	**Solution**
Excessive orange peel	Poor atomization	Increase air pressure, decrease material
Spray too wet—runs	Too close, too slow, too much overlap	Increase distance, move faster, less overlap
Spray too dry—dry spray	Too far, too fast, not enough overlap	Decrease distance, move slower, more overlap
Air hose or paint suit touches wet paint	Lack of coordination	Think while you spray
Paint gun drips	Cup lid leaks	Properly install cup lid or replace
Incomplete coverage or poor hiding	Not enough coats of paint	Apply enough paint
Tiger stripes	Too much air pressure, heeling	Decrease air pressure, keep fan perpendicular
Mottling	Metallic not evenly dispersed	Clean air cap properly, adjust spray gun

Figure 27-14. *This table lists spray gun adjustment problems, causes, and solutions.*

Body Position

One aspect of spray technique that is often overlooked is ***body position***. Proper spray technique is much easier if the painter is positioned near one end of the panel. This allows the painter to stretch for the entire stroke. The stroke length will be the length of the panel, or if the panel is long, the stroke will be the length of the painter's reach.

Figure 27-15 shows the recommended body position. The painter has one foot positioned near the end of the panel. For a right-handed painter, it should be the right foot. A left-handed painter should use the left foot. Proper positioning and stretching will allow the painter to maintain a consistent distance and speed. If the painter were positioned in the center of the panel, the stroke would be interrupted as the paint gun is moved in front of the painter's body.

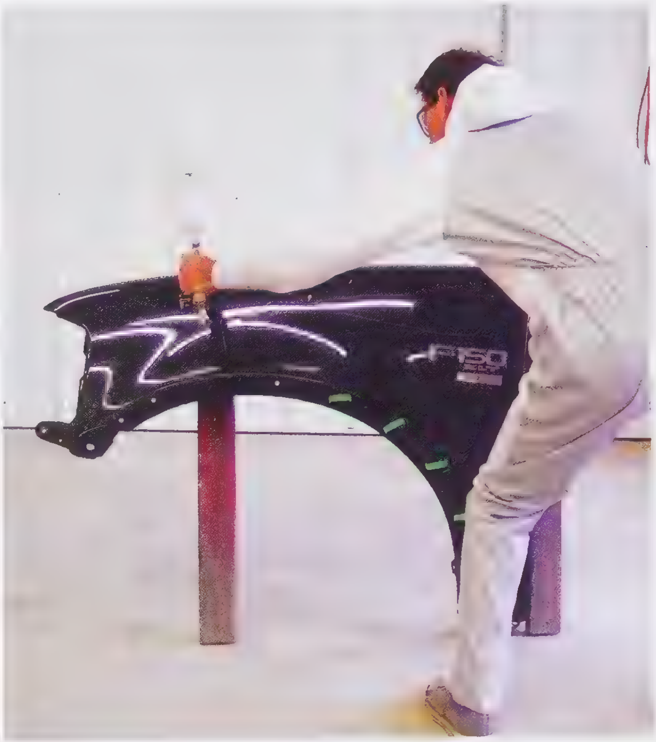


Figure 27-15. *Proper positioning and stretching will allow the painter to maintain a consistent distance and speed.*

Fan Orientation

For consistent paint coverage, the fan must strike the surface uniformly. See **Figure 27-16**. Any fan orientation other than perpendicular to the panel is known as ***heeling***, **Figure 27-17**. Heeling will cause more paint to be deposited on one end of the fan than on the other.

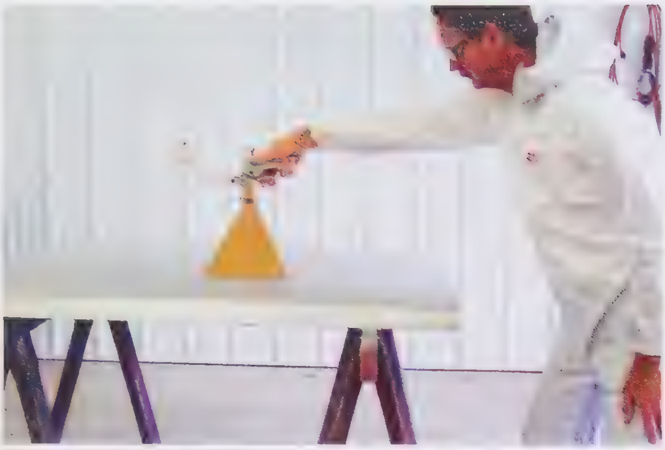


Figure 27-16. *This cardboard cutout represents a fan. Notice how the technician's wrist is bent to properly orient the fan.*

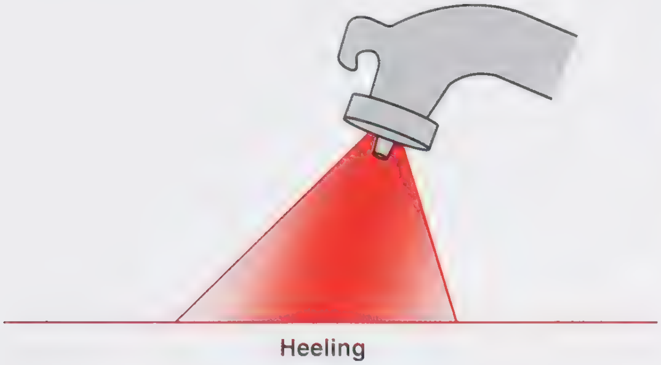


Figure 27-17. *Heeling describes a fan pattern that does not strike the panel uniformly. The spray gun is tilted, causing the fan to deposit more paint on one side and less paint on the other side of the fan pattern.*

When spraying a horizontal surface, the technician's wrist must generally be bent as shown in **Figure 27-18**. This will ensure that the fan strikes the panel uniformly. Vertical surfaces may also require wrist movement to orient the fan properly. **Figure 27-19** shows the spraying of a convex panel that curves under. To keep the fan uniform, the technician must tilt the spray gun to follow the panel contour. Proper fan orientation takes practice to master.

Distance

A consistent distance—from spray gun to panel—will result in a uniform coat of paint. For conventional spray guns, the ideal distance is 8–10". For HVLP spray guns, this distance is 4–6". Most vehicle surfaces are not flat. Therefore, the paint technician must maintain the proper gun distance while following the contour of the panel as it is being painted. If the painter does not follow the changing contour of the panel, the resulting problem is called ***arcing***. See **Figure 27-20**.

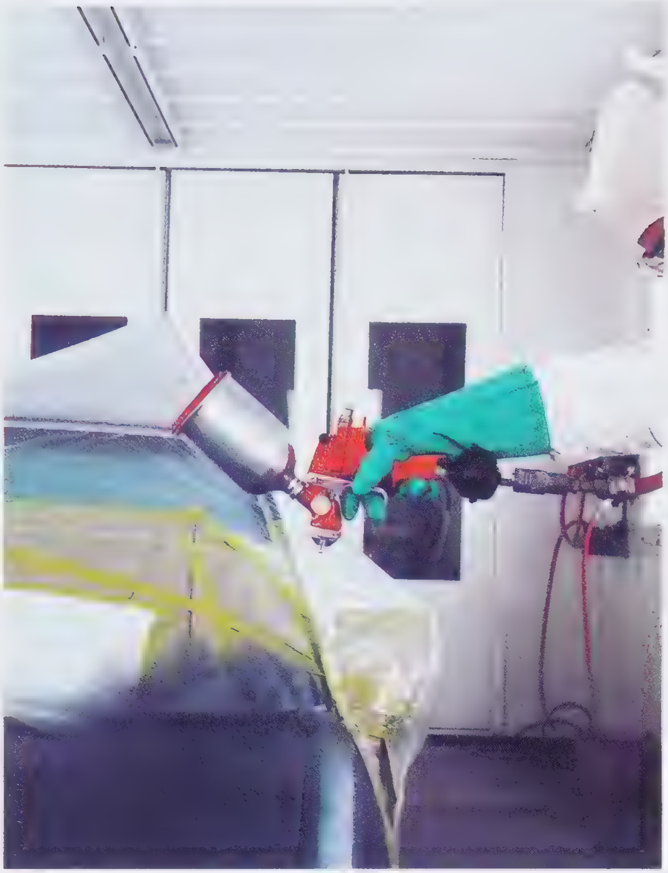


Figure 27-18. *The painter's wrist must be bent when spraying a horizontal surface.*

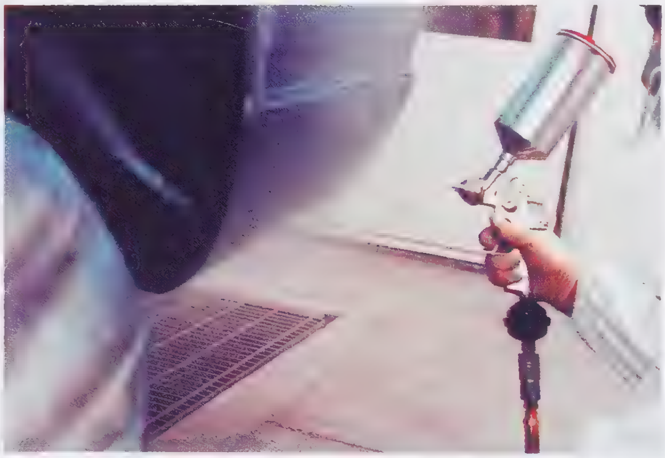


Figure 27-19. *The bottom of this panel curves under. To maintain a uniform spray pattern, the spray gun must be tilted.*

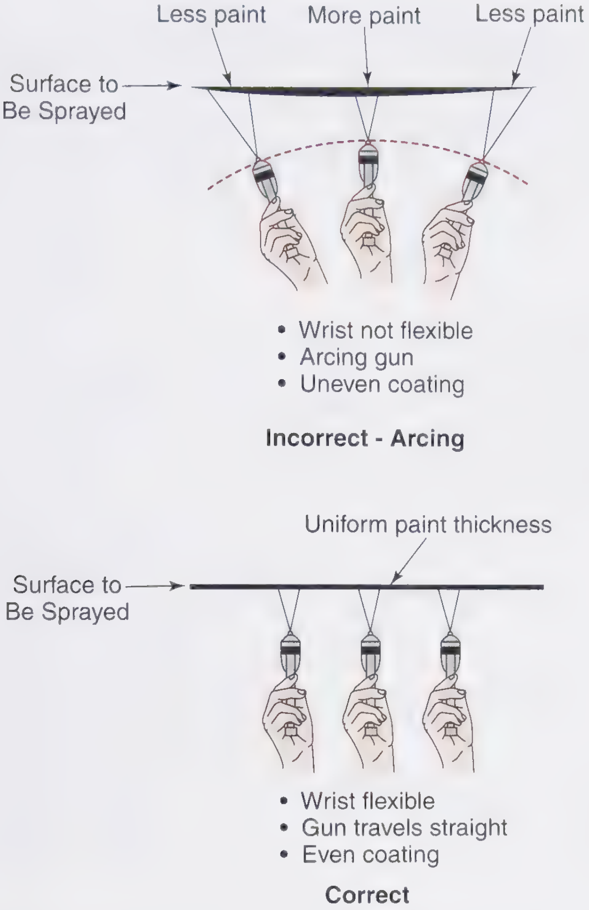


Figure 27-20. *Arcing causes uneven paint application. (DeVilbiss)*

Spraying too close to the panel will put too much paint on the surface, causing runs. Some of the solvent is designed to evaporate while the paint is sprayed. Spraying too close will not allow this solvent to evaporate, and instead, it is applied to the surface. Spraying too close also causes orange peel because there is not enough time, due to the short distance, for the air pressure to fully atomize the paint. Spraying too far from the surface causes some of the atomized paint to dry before it reaches the panel, leaving a rough, textured surface.

Travel Speed

Consistent spray gun ***travel speed*** is just as important as maintaining proper distance. Travel speed is the rate at which the tech moves the gun across the panel. If the travel speed is too slow, too much paint will build up. If the travel speed is too fast, not enough paint will be deposited on the surface. As a rule of thumb, the travel speed for a conventional gun should be about 1' per second.

An HVLP spray gun is held closer to the panel and moved faster than a conventional spray gun. For an HVLP spray gun, the travel speed should be about 1 1/2' per second. Practice consistent travel speed by measuring a panel and timing the travel. Practice until spray gun travel speed control becomes second nature.

Distance and travel speed are the two main factors that determine the amount of paint applied to a panel. **Figure 27-21** shows spray gun movement on horizontal and vertical panels. Keep the spray gun fan perpendicular to the panel with a uniform orientation while moving it at a consistent speed and distance.

It is important to remember that distance and speed are interrelated. The distances and speeds suggested previously are starting points. You must find the technique that works best for you. Some painters like to be close in and move fast; others want to be farther away and move slowly. Different brands of spray guns may require modifications to your technique.

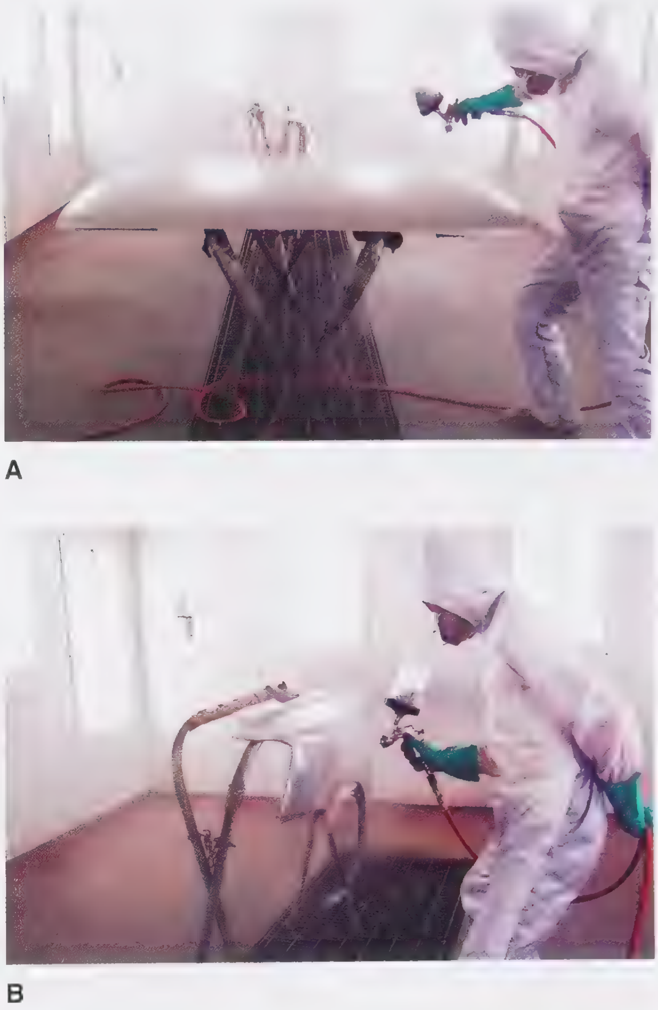


Figure 27-21. *A—Maintain consistent spray gun distance and travel speed on horizontal panels. B—Technician keeps the fan perpendicular to the vertical panel.*

Practice distance and speed together. Fasten a stick of the proper length to the spray gun, as shown in **Figure 27-22**, and mark off a panel into 1' sections. Practice holding the spray gun the proper distance from the panel and moving at the proper speed. On a curved panel, practice moving the gun so that the stick lightly contacts the panel during the entire stroke.

Overlap

When painting, each stroke should ***overlap*** the previous stroke by 50%. See **Figure 27-23**. Overlap is the amount of fan that is sprayed over the previous stroke. Overlap ensures the smooth blending of paint by covering half of the previous stroke with the following stroke. Usually there is one stroke from right to left and one stroke from left to right. Two-stroke coverage ensures that the entire surface receives enough paint. Each portion of the panel is covered by two strokes.

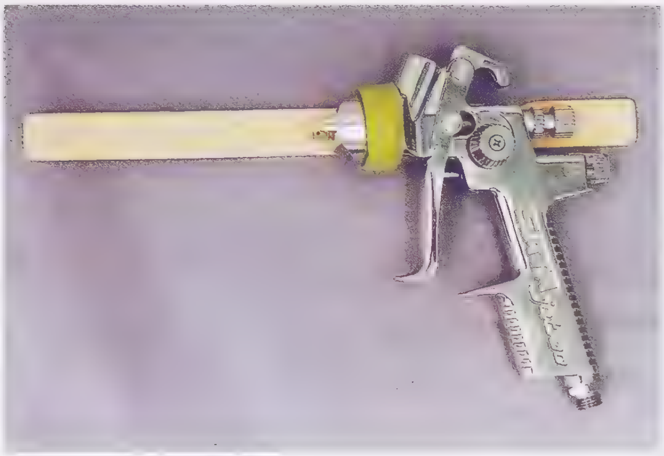
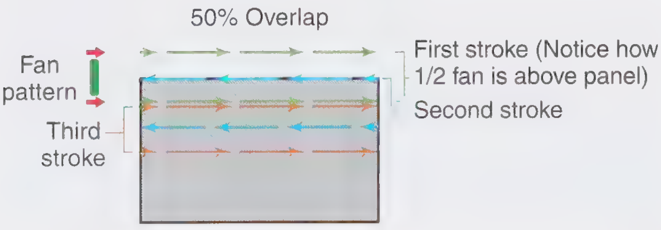


Figure 27-22. *A painter can practice maintaining a consistent distance by taping a paint stick of the correct length to the spray gun.*



The middle of the fan pattern is aimed at the edge of the previous stroke

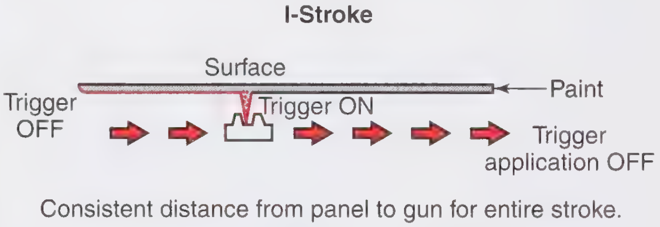
Figure 27-23. *In a 50% overlap, the next coat covers half of the previous coat.*

Proper overlap technique requires practice. The technician should aim the spray gun so the center of the spray pattern hits the edge of the previous stroke. This overlapping technique is repeated until the entire panel is coated. A 75% overlap means that each stroke covers 3/4 of the previous stroke. This method applies more paint to the surface than a standard 50% overlap.

Stroke

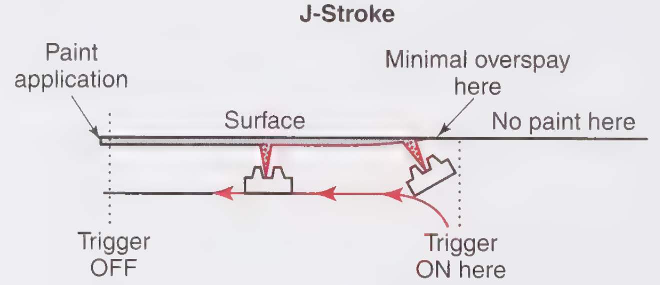
The movement of the gun from one end of the panel to the other is called ***stroke***. To make an I-stroke, the trigger is pulled at the beginning of each stroke and released at the end. See **Figure 27-24**.

Blending calls for a modification of the I-stroke called the J-stroke. Blending is a technique used to hide a paint edge. To make a J-stroke, the spray gun is held so it points away from the area that will not be painted and is toward the area that will be painted. See **Figure 27-25**. When making a J-stroke, the spray gun is triggered as it is moved toward the panel. During the stroke, the painter orients the spray gun perpendicular to the panel by wrist rotation. At the very end of the return stroke, the painter bends the wrist and turns the gun away from the area that will not be painted and triggers the gun off. The purpose



Consistent distance from panel to gun for entire stroke.

Figure 27-24. *The I-stroke is used in panel painting.*



Spray gun tilts away from area that will not be painted, on the next stroke.

Figure 27-25. *The J-stroke is used in blending. Bending the wrist prevents overspray on the blended area.*

of a J-stroke is to prevent dry overspray at the edge of a blend. By pointing the spray gun toward the spray area and away from the area that will not be painted, dry overspray is minimized. Dry overspray makes a blend obvious, the exact opposite of what a blend should be.

Triggering

Triggering is a concept that is often difficult for the beginner to learn. Proper triggering involves releasing the trigger at the end of the stroke and pulling the trigger just before the stroke begins. Pull the trigger in one smooth, fluid motion. Pull too slowly and the spray pattern can be too heavy and run. Pull too quickly and the pattern may not fully develop.

Triggering is especially important when a panel is painted in sections. For example, **Figure 27-26** shows the spray pattern for a truck's bed side. This long panel will be painted in three sections. The trigger is pulled at the beginning of each forward stroke and released at the end of each forward stroke. At the beginning of the return stroke, the trigger is again pulled. Releasing the trigger at the end of the stroke prevents excess paint buildup where the three sections meet/overlap. Triggering is not as important when the panel is short and does not need to be divided into sections. For example, a hood is usually painted in one section. Releasing the trigger at the end of the forward stroke will only prevent paint buildup on the masking paper that is protecting the windshield.

Normally, the material adjustment knob is used to control the amount of paint discharged onto a surface, but skillful use of the trigger allows experienced painters to reduce the amount of paint applied without touching the adjustment knob. Simply put, partially pulling the trigger discharges less paint. When spraying a dry coat, for example, some painters will partially pull the trigger rather than change the fluid adjustment setting. This is an advanced technique.

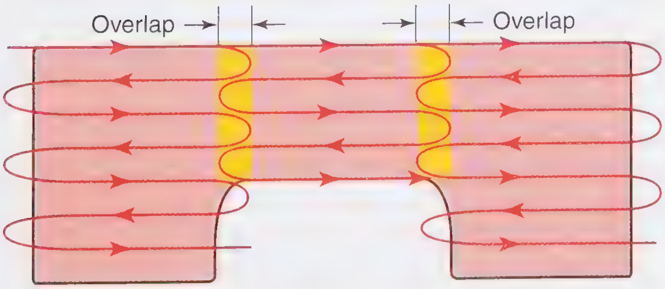


Figure 27-26. *A long panel can be sprayed in sections. There will be an overlap where the sections meet.*

Match the Technique to the Job

Different applications call for different kinds of paint coats. Several different types of coats are available to the paint technician. Often, paint manufacturers' instructions will recommend a specific type of coat. The types of coating options available are explained below.

Medium Wet Coat

This is the most commonly used type of paint coat. To apply a medium wet coat with an HVLP spray gun, hold the spray gun 6" from the surface. Your stroke should be 1 1/2 seconds/foot at a 50% overlap with the spray gun set at manufacturer's recommended air pressure. The fan and material are set below maximum. For a conventional spray gun: 8"-10" from surface, 1 second/foot, 50% overlap, spray gun set at manufacturer's recommended air pressure, fan and material set below maximum. Base coat should be applied in medium wet coats because they are formulated to be applied in thin coats, unlike clearcoats that are sprayed on wet and heavy. The best way to understand the difference is to compare them. When compared to a full wet coat, a medium wet coat puts less material onto the surface, dries faster, and is not as glossy immediately after spraying.

Full Wet Coat

A full wet coat applies more material than a medium wet coat. A full wet coat will allow maximum flow out, increasing gloss. See **Figure 27-27**. This type of coat is difficult to apply to a vertical surface without runs.

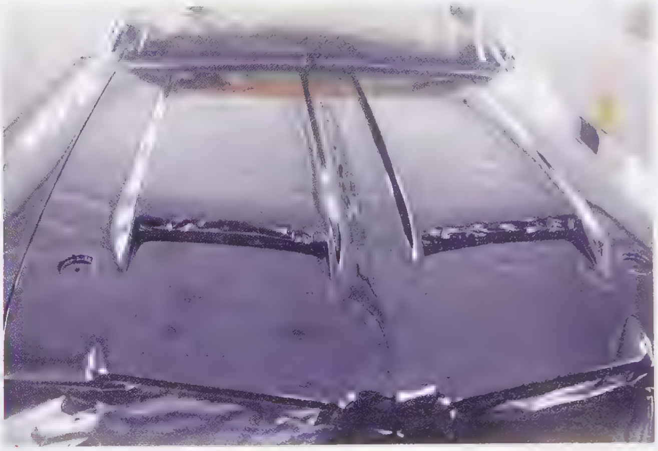


Figure 27-27. *A full wet coat of clear was applied to this vintage hood to achieve maximum gloss.*

There two ways to spray a full wet coat. The first way is to adjust the pattern control knob to decrease the size of the fan or adjust the material control knob to increase the amount of paint in the fan. Keep travel speed, distance, and overlap the same as a medium wet coat. The second way is to keep the fan and material settings the same, but move the gun slightly closer to the panel, reduce your spray gun travel speed with more overlap. One of the few times a full wet coat is called for is when spraying the last coat(s) of clear. A drawback of applying too wet is the risk of trapping solvents.

Drop Coat

Some paint manufacturers recommend a drop coat be sprayed once the basecoat has covered the undercoat. A drop coat is the last coat of basecoat. A drop coat will set the metallic and prevent mottling. ***Mottling*** occurs when the aluminum flakes in a metallic color are not uniformly distributed. In mottling, the applied paint has light and dark bands or spots because the spray gun is not applying a uniform amount of paint. Typically, mottling is caused by a dirty air cap, or the spray gun is not held perpendicular to the surface. Usually, a drop coat is sprayed at a lower than recommended air pressure setting—usually 25 psi for a conventional spray gun and 5–7 psi for an HVLP spray gun. All other aspects of spraying remain the same.

Mist Coat

Another method used to prevent mottling is a mist coat. A mist coat is the last coat of a metallic paint and is sprayed at twice the normal distance from the surface. This coat is sprayed onto the last coat of wet paint. The mist coat will settle on and melt into the wet paint.

Tack Coat

A tack coat is another type of dry coat. This coat is sprayed first, before other coats. The tack coat makes a rough surface so the next coats can adhere to it and is often used before spraying a full wet coat of single-stage. A tack coat can be applied by reducing the amount of material, increasing distance, or by moving faster.

Blend Coat

A blend coat is an over reduced (30–50%) basecoat sprayed at one-half normal air pressure. The blend coat evens out metallic distribution to prevent mottling and makes a blend invisible. The blend coat is sprayed as the last coat of basecoat.

Paint Type

All paints are not sprayed in the same way. Some paints, such as dark basecoats, are easy to spray. The paint covers the undercoat in one or two coats without mottling. Other paints, such as white basecoats, may be more difficult to spray because of a tendency to run. Light colored metallics, such as silver, may easily mottle. Basecoats should be applied for coverage; each coat applied as smoothly as possible. Clearcoat can be difficult to spray, especially a fast, dry, clear. The first coat of clear will brighten the basecoat so it is easy to see how the clearcoat is flowing out. The remaining coats of clear will be applied over a shiny clearcoat, making it difficult to judge the application technique. Be careful on second or third coats of clear. Follow the established pattern and rhythm from the previous coats. Waterborne basecoats will have a specific application procedure depending on the brand of paint. This procedure can range from one quick coat immediately followed with a heavy coat to three coats applied in the same way as solvent borne basecoat.

Spraying Body Panels

The basics of spray gun handling can be applied to refinish any panel on a vehicle. This section is broken down into two parts—preliminary information and specific panel refinishing. Always keep in mind that spraying has a rhythm and the painter will establish this rhythm on the first coat of a panel. By maintaining a rhythm, the painter can apply additional coats of basecoat and clearcoat with satisfactory results. Spray painting is often referred to as an art. In this art, the painter blends all the variables—spray gun adjustments, spray technique, and paint type.

Painting Long Panels

When painting a long panel, it can be divided into sections. When using this method, the technician sprays everything within reach. The overlap area should be staggered in successive coats as shown in **Figure 27-28**. To avoid overlap, the panel can be walked. **Figure 27-29** shows a technician ***walking the panel***. In this method, the painter moves the spray gun down the length of the vehicle. This method requires considerable skill and will only work if the painter moves smoothly, without hesitation or skips. Walking demands that the air hose be controlled and kept out of the painter's way.

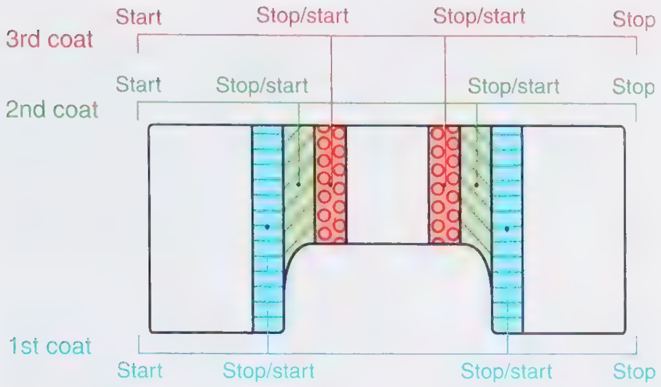


Figure 27-28. *This diagram shows the staggering of overlap areas when painting a long panel in sections. Colored sections are overlap area.*

Figure 27-29. *This painter is walking the length of the truck bed side. This requires considerable skill. Notice the paint gloss.*

Panel Refinishing

This section explains how each panel of a vehicle should be sprayed. Keep in mind that in most cases, painting starts off the panel and spraying continues past the wet edge. A wet edge is the border between an already painted surface and a non-painted surface. When painting a panel, as in a repair, the paint gun trigger is released when the paint gun reaches the end of the panel. When painting a complete vehicle, seeing the wet edge is important to maintaining the desired amount of overlap (between 50% and 75%).

One factor to emphasize in this section is the painter must constantly change body position while spraying. Painting requires stretching, squatting, and reaching. Spraying with a full cup of paint is a demanding, physical job. Always keep the fan properly oriented toward the surface. This will require concentration as well as the coordinated movement of the feet, legs, arm, wrist, and hand.

Painting a horizontal surface such as a hood requires the application of more paint for good internal flow out. If one painter is spraying a hood, the center of the first stroke should be aimed at one edge. The next stroke, with a 50% overlap, will cover up to the edge. Keep moving toward the center of the hood with each successive stroke. Once the center is reached, the painter should switch to the other side of the vehicle and work from the center to the edge. **Figure 27-30** shows this technique. If two painters are available, start in the center with one painter on each side, painting successive strokes away from the center.

The roof is sprayed in the same way as a hood. Start at the edge and work toward the other side, switching sides at the center. The height of a car roof will not be a problem for most painters. However, the sail panel will. Paint to the middle of the sail panel so that the paint on the quarter panel can be overlapped.

The roof of a pickup truck, SUV, or van will be tall enough to cause a problem for most painters. The roof on a pickup truck can be sprayed in the same way as a car roof if the painter stands on a support. The roof of an SUV or van is much easier to paint if there are two painters, one on each side. They should start in the center and work out from there. The roof will need to be divided into sections.

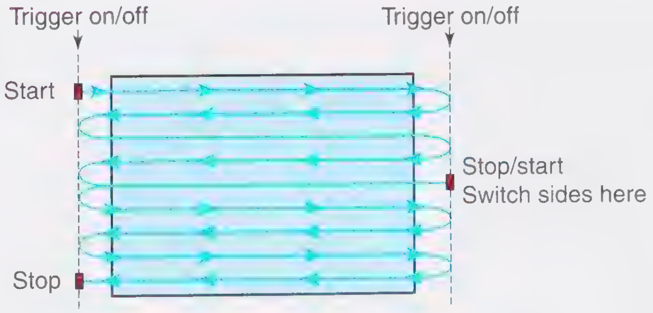


Figure 27-30. *This diagram shows the proper sequence to follow when painting a hood. Start at one edge and work toward the center. Switch sides and work from the center out.*

A deck lid is short enough to be sprayed with strokes either parallel to the length of the vehicle or perpendicular to the length of the vehicle. Start at one edge just as you would when painting a hood or roof.

A fender can be sprayed in a downdraft booth as shown in **Figure 27-31**. Spray the wheel well first, then go up to the top of the fender and work your way down. When the wheel arch is reached, spray the area ahead of the wheel arch. Pick up the wet edge behind the wheel arch and spray to the bottom. In a cross draft booth, start at the bottom and work up. Be careful of runs if the wheel arch sticks out more than 1" from the fender.

Spray the quarter panel in the same way as the fender. Spray the wheel well first; then start at the sail panel and work down to the wheel arch. Spray the area in front of the arch, and then spray behind the arch.

When painting a door, the window frame should be sprayed first. Set the spray gun pattern accordingly and watch for runs in this narrow area. The door panel should be sprayed next. Work from top to bottom. Body lines are another place where runs are common, so focus on proper technique. When painting a rocker panel or any low area such as a splash pan or valence, the painter will need to get down low, into a squat—balanced and ready. The spray gun will need to be tilted as shown in **Figure 27-32**. A rocker panel can be difficult to paint because of limited access. Some shops will raise the vehicle on jack stands to improve access to the rockers and lower edges of body panels.

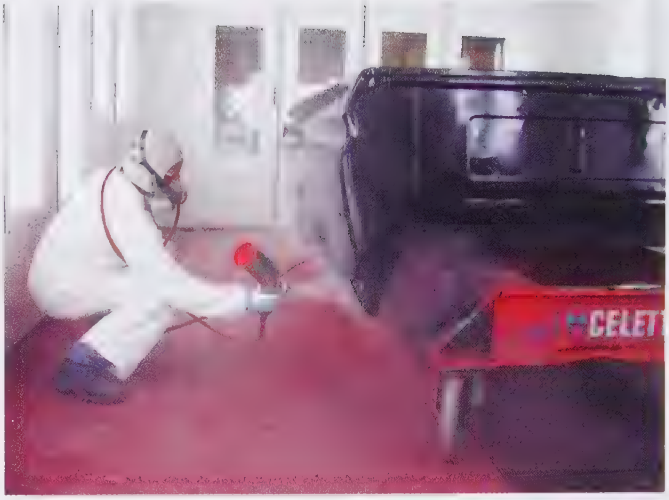


Figure 27-32. *The painter must squat to spray low areas like rocker panels or this lower part of a bed side. The truck bed has been removed from the frame and placed on a dolly to give the painter improved access.*

The hidden areas inside a door, such as the doorjamb, are painted when a quarter panel is replaced. To spray in these confined areas, adjust the paint fan down to a narrow spray pattern. Adjust the material knob by turning it in. If the material is not set to the fan, too much paint will be applied. Set the air pressure after the fan and material are set. If the area is tall and narrow, then spray with strokes that are parallel to the long dimension. **Figure 27-33** illustrates this technique. This method will prevent the runs that may be caused by moving side to side. Another way to do this is to turn the air cap so the horns are up and down. This gives a side-to-side rather than up-and-down spray pattern.

Front end collisions typically require the repair or replacement of the radiator support. When a radiator support is replaced, the new part must be painted. Painting can be difficult because of the confined area and numerous angles. A touchup spray gun works well in tight spaces. Be sure to remove as many obstructions as possible before painting. Be deliberate when masking off surrounding areas.

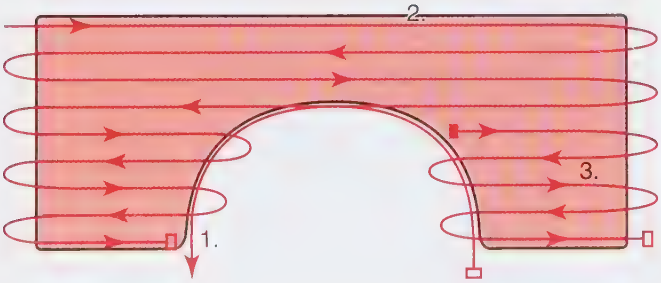


Figure 27-31. *Here is how to spray a fender in a down-draft spray booth. Start at the top and work to the wheel opening. Continue to the area ahead of the wheel opening then switch to the area behind the wheel opening.*

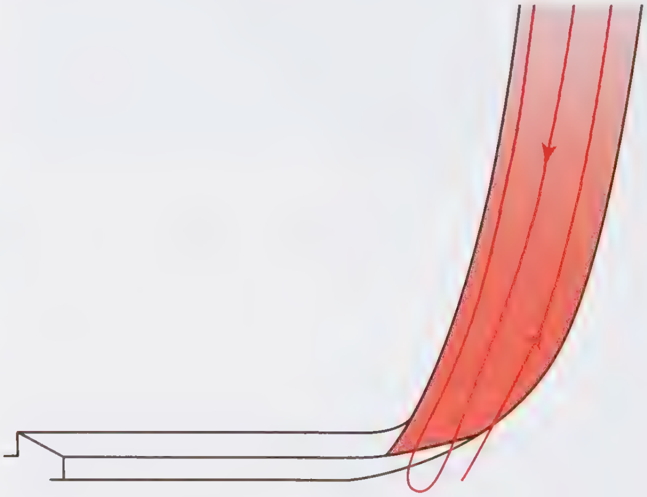


Figure 27-33. *Follow the long dimension when spraying a long narrow panel.*

Right angles are difficult to spray even for experienced technicians. **Figure 27-34** shows two panels at right angles to each other. The problem is caused by a rapid buildup of excess paint at the point where the two panels meet. The best way to paint these is to first spray a band of paint at the right angle. This technique is sometimes called ***banding***. Use the band as a beginning and stopping point. Spray one panel, and then paint the other as shown in **Figure 27-35**.

Painting the broad side of a van or the large expanse of a truck's bed side calls for the same painting strategy that is used on a quarter panel or fender. The only difference being the panel must be divided into sections or walked. Spray the wheel well first. Then work from top to bottom.

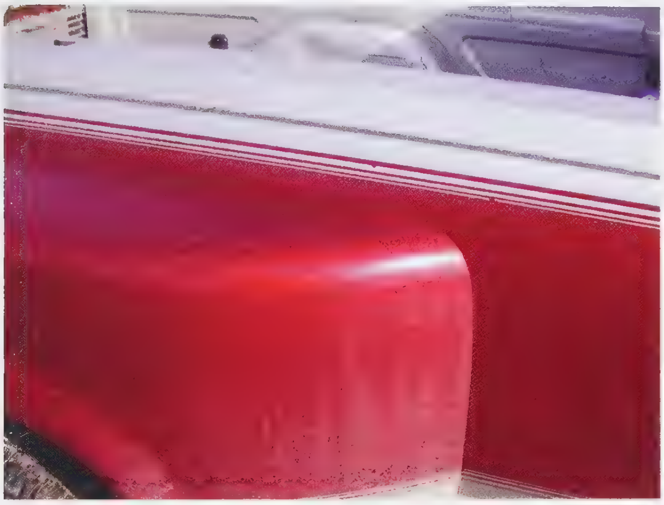
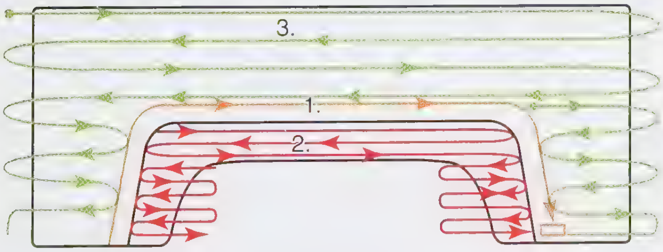


Figure 27-34. *This pickup truck has rear fenders. The rear fenders are at right angles to the bed side. The corner where the fender meets the bed is a place where runs are common.*



1. Spray band around rear fender
2. Spray fender
3. Spray bed

Figure 27-35. *Banding is the technique use to avoid runs. First spray a band of paint where the panels meet. Spray the fender, and then spray the bed side.*

Painting the inside of a pickup truck bed requires several different strategies. When just one inside panel of a bed needs to be painted, the painter can stand inside the bed to spray. When the entire inside of the bed must be painted, the painter should stand outside of the bed. Full-size pickup beds are difficult to reach. One way to get around this problem is to position the painter on a stand. Another way to spray the inside of a pickup truck bed is to remove the bed from the pickup frame and paint the bed separately. The bed can be placed on stands, giving the painter greater access. In either case, the painter must spray in an awkward position. The painter must reach around to spray the inside of the bed. It can be difficult to keep the spray gun, air hose, and sleeves out of the wet paint. When spraying the entire bed, spray the floor first. Spray in sections. Start at the center and work to one side. Then go to the center and spray to the other side. Next, spray the sides. Spraying the wheel wells can cause problems. Try banding the right angles around the wheel well, and then spray the wheel well and the sides around it.

Other Painting Considerations

Every detail is important when painting. Seemingly unimportant factors, such as failure to thoroughly wash the vehicle or wearing a dirty painting suit, will result in a poor finish. There are no shortcuts to quality painting. By following best practices, developed and tested by the industry, technicians will give themselves the best chance to consistently produce excellent results. Controlling the air hose, understanding spray booth airflow, and being dedicated to thorough spray gun maintenance are examples of the kind of attention to detail that separates the expert painter from the amateur.

Spray Booth Type

A good rule of thumb is to spray with, not against, the direction of airflow in the spray booth. In this way, the painter is not fighting the air movement. By spraying with the airflow, overspray will be drawn away from wet paint, rather than pushed into the wet paint. In a cross-draft booth, if the airflow is from the front of the vehicle to the rear of the vehicle, spray the vehicle in the direction of the airflow, front to back. In a down-draft booth, spray the vehicle from top to bottom. **Figure 27-36** shows the spray sequence in a cross-draft booth. **Figure 27-37** shows the sequence in a down-draft booth. Both of these are for ***complete paint jobs***, where the entire vehicle is refinished. This is not a common practice in most body shops. Usually, only part of a vehicle is repainted.

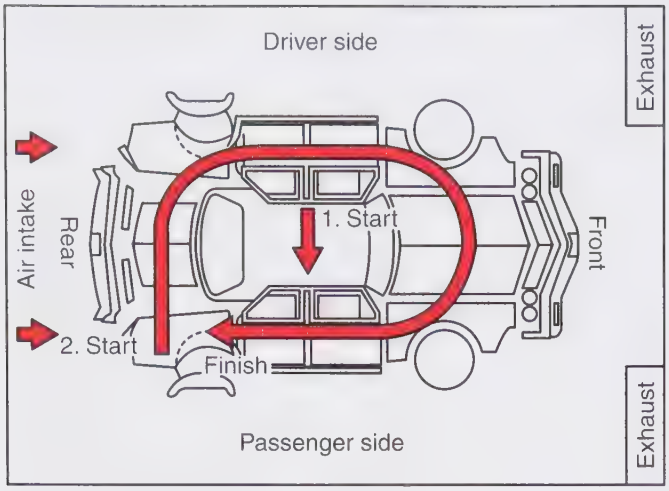

Driver side
Exhaust
Air intake
Rear
1. Start
Front
2. Start
Finish
Passenger side
Exhaust

Figure 27-36. *This is the sequence to follow for a complete paint in a cross-draft booth. (Dupont)*

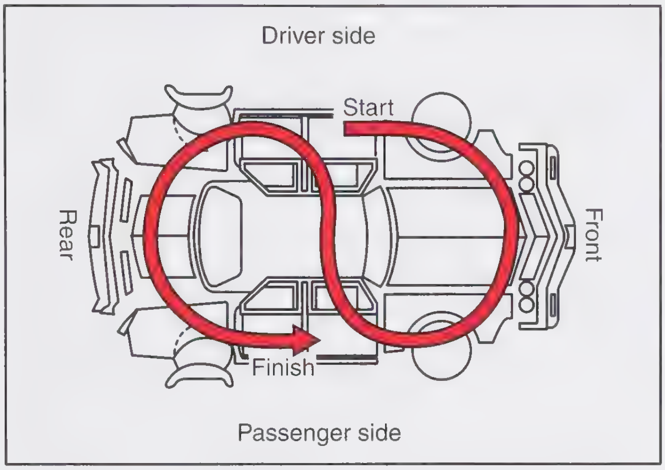

Driver side
Start
Rear
Front
Finish
Passenger side

Figure 27-37. *This is the sequence to follow for a complete paint in a down-draft booth. (Dupont)*

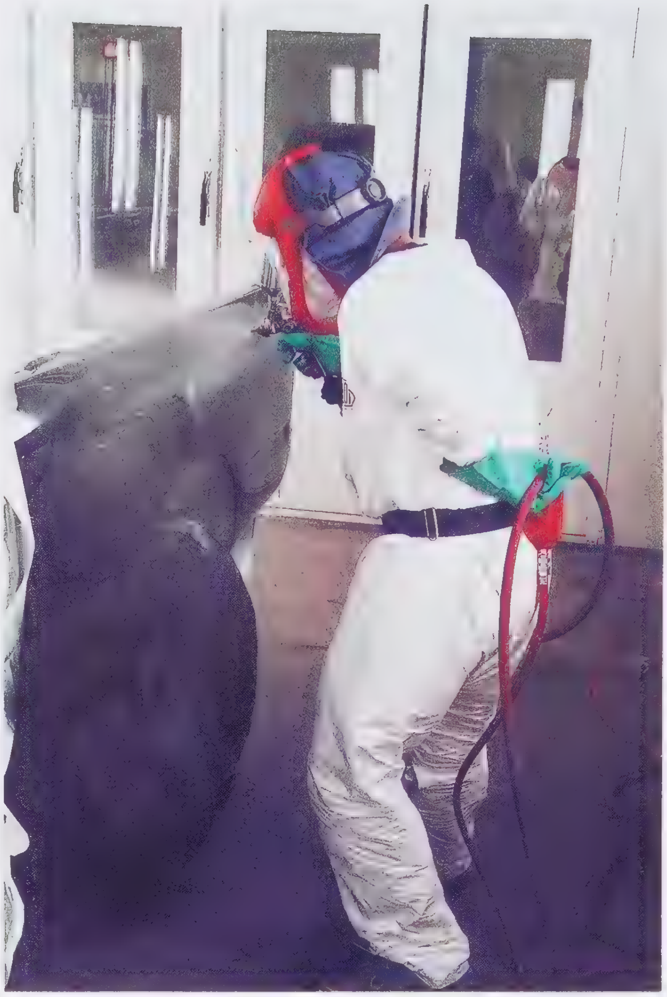


Figure 27-38. *This painter controls the air hose by keeping it behind the back and out of the way.*

Air Hose

There will always be at least one ***air hose*** in use when spraying a vehicle. If the painter wears a supplied air respirator, there may be two air hoses to contend with. Air hoses present at least two problems. First, when lying on the floor, the air hose may get in the painter's way. A misplaced air hose can cause the painter to trip or stumble. These problems can be prevented if the painter handles the hoses as shown in **Figure 27-38**.

Second, the air hose may touch the wet paint. If the hose is covered with dirt, the dirt will be transferred to the paint. Even if the hose is clean, it will mar wet paint. See **Figure 27-39**. To prevent this problem, keep the hose away from the vehicle. The painter should always know where the air hose is.

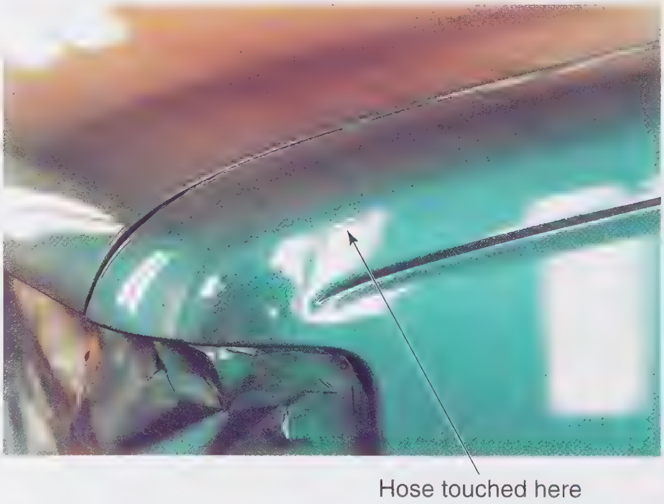

Hose touched here

Figure 27-39. *When leaning over to paint the hood, a careless technician allowed the air hose to touch the wet clearcoat on this fender.*

Spray Gun Cleaning

Spray guns must be cleaned after every use. Spray gun cleaning is dead production time, but it absolutely must be done. A clean spray gun sprays better than a dirty gun. Paint flows better when passages inside the gun area are clean. Dried paint inside a spray gun may soften and spurt out with the fresh paint, contaminating the new finish.

NOTE

Waterborne paint and solvent paint cannot be mixed together, even as waste paint. Waterborne paint requires a dedicated spray gun to prevent a reaction between residual paint in the spray gun after cleaning and paint in the cup. Cleaning a waterborne spray gun may require a special cleaning solvent obtained from the paint manufacturer. A separate gun washer and liquid waste barrel is required for waterborne paint.

Loading a spray gun with thinner and then spraying it out is not a recommended way to clean a spray gun because it puts VOCs into the atmosphere. See **Figure 27-40**.

To manually clean a gravity-feed spray gun, first empty the paint from the cup. Load the cup about one-third full of clean thinner, install the lid, and shake the gun. This will allow the thinner to clean the underside of the lid. Trigger the gun (without air pressure) so thinner flows out. The thinner can be directed into a paint mixing cup, if the cup needs to be cleaned out, or into the waste thinner barrel, **Figure 27-41**.

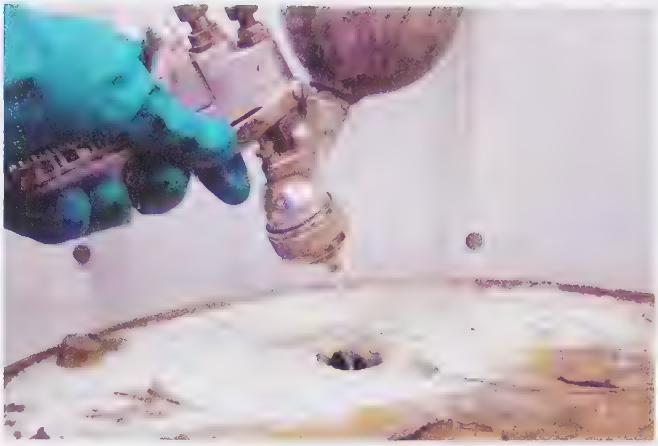


Figure 27-41. *Load the cup with clean thinner and trigger the spray gun (without air pressure) over the waste thinner barrel to clean the cup.*

WORKING SMART

Some painters leave thinner in the gun and seal the cup threads. This keeps the thinner in the gun and will help soften any hardened paint in the paint passages.

If a disposable cup liner is used, the cup can be removed and thinner poured or squirted inside the gun. See **Figure 27-42**. Triggering the gun allows the thinner to flow out. Remove the needle and wipe it with a thinner-moistened cloth. Reinstall the needle. Once the cup is emptied, remove the air cap. Use a brush to clean the air cap and fluid tip. If the orifices are clogged, use a toothpick to remove dried paint. Never use a metal tool to clean the orifices as this may enlarge the hole.

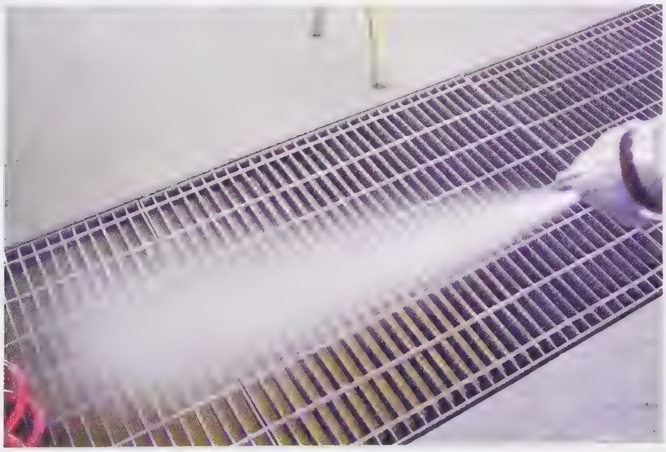


Figure 27-40. *Spraying thinner to clean the spray gun needlessly contaminates the air with VOCs.*

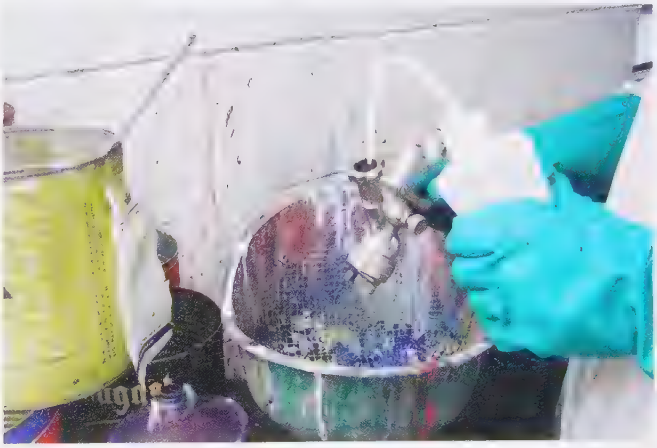


Figure 27-42. *Trigger the spray gun (without air pressure) over the waste thinner barrel while squirting thinner through the spray gun.*

Remove the needle and wipe it with a thinner-moistened rag. Use a brush to clean inside the inside of the paint tube. See **Figure 27-43**. A dirty spray gun may require fluid tip removal and brushing the entire paint passage. Clean the threads of the paint cup and lid with a thinner-moistened cloth as shown in **Figure 27-44**. Rinse the spray gun with thinner. Only the portion of the spray gun that holds or carries paint needs to be cleaned. The cleaning thinner is hazardous waste, so minimize the amount used.

A siphon feed or gravity feed spray gun can be cleaned in a gun cleaner, **Figure 27-45**. The spray gun and cup are separated, the paint passage of the spray gun is positioned over a nozzle, and the gun trigger is blocked open. The cup is placed over another nozzle. After the lid is closed and the gun cleaner is turned on, a pump in the cleaner forces thinner through the paint passages and into the cup. How clean the spray gun becomes is related to how clean the thinner is. Once the cleaning cycle is completed, the gun is removed and wiped off.

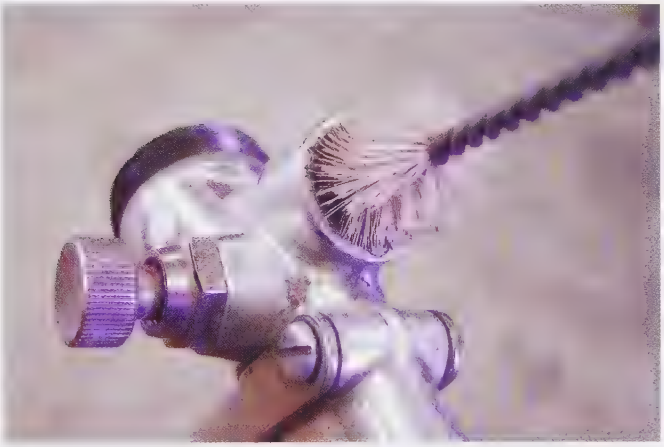


Figure 27-43. *A brush can reach internal passageways.*

Figure 27-44. *Thoroughly clean the threads of the cup and the cup lid. Dried paint on the threads or on the cup lid will interfere with a tight seal, causing the cup to leak.*

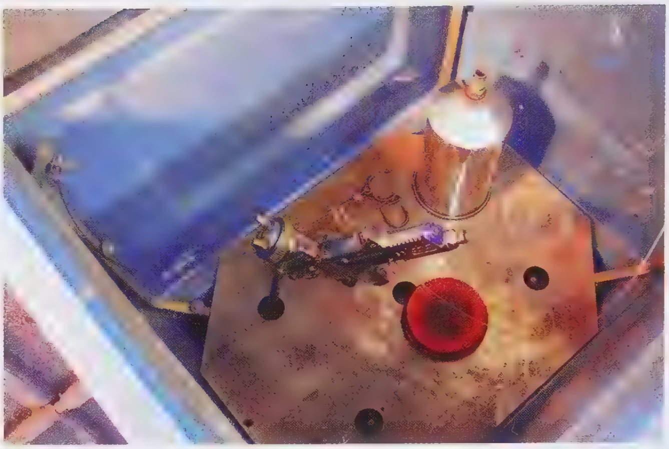


Figure 27-45. *In this gun cleaner, the gravity feed cup and gun are positioned on nozzles so thinner can be pumped through them.*

NOTE

Plastic gaskets inside the body of the spray gun prevent paint from leaking around the needle. These plastic gaskets swab the needle as the needle moves in and out of the gasket. The gaskets should be treated with spray gun lubricant for proper function. There are also gaskets in the air valve. These gaskets prevent air leaks. As with needle gaskets, these gaskets should be kept lubricated.

Summary

- Speed and distance are the two key variables of spray technique.
- Flow out is the tendency of wet paint to level and smooth out after spraying. The wetter the paint, the longer the leveling time.
- There are three possible adjustments on spray guns: fan size and shape, material flow, and air pressure.
- The pattern control knob regulates the amount of air that flows through the air horns. It controls size and shape of the spray pattern.
- The fluid control knob controls the amount of paint that is introduced into the airstream.
- The air pressure control knob is used to adjust air pressure.
- Changing one of the spray gun adjustments will affect the other two.
- A pattern test is performed to fine-tune spray gun adjustments.

- A flood test is a check of paint distribution within the spray pattern.
- While spraying, the paint technician must watch the paint as it is applied and keep an eye on the path ahead.
- Once the first stroke (one pass of the spray gun at a specific distance and speed) is made, all subsequent strokes should match the initial stroke.
- Proper spray technique is easier to maintain if the painter is positioned near one end of the panel.
- For consistent paint coverage, the fan must strike the surface uniformly. To keep the fan uniform, the technician must tilt the spray gun to follow the panel contour.
- Travel speed should be about 1 1/2' per second for HVLP guns and 1' per second for conventional spray guns.
- When painting, each stroke should overlap the previous stroke by 50%.
- A medium wet coat is the most common.
- Spray guns must be cleaned after every use.

Review Questions

Please do not write in this textbook. Place your answer on a separate sheet of paper.

1. Paint leveling after spraying is called ______.
2. Decrease in air pressure will cause a drier spray. True or False?
3. Material, fan, air pressure is the recommended sequence when setting up a spray gun. True or False?
4. The ______ moves out of the air cap when the spray gun trigger is pulled back.
5. If an HVLP spray gun is supplied with 20 psi of air at the inlet, it will discharge 20 psi from the air cap. True or False?
6. Decreased travel speed will apply a wetter coat of paint. True or False?
7. What parts of the spray gun should be cleaned when the fan shows a split pattern?
8. Explain the proper way to make a flood test.
9. A loose fluid tip causes ______.
10. Explain how to keep the air hose or hoses out of the way when spraying.
11. ______ is the painter's ability to stretch when spraying a vehicle.
12. The painter should position himself at the center of a panel when spraying. True or False?
13. A spray fan does not strike the panel uniformly. The problem is called ______.
14. Triggering, distance, and travel speed are all equally important elements of spray gun handling. True or False?
15. The correct amount of overlap for most painting is ______.
16. When spraying a metallic paint, a drop coat is applied last at about 25 psi. The purpose of a drop coat is to set the metallic and prevent mottling. True or False?
17. Before you spray a full wet coat of clear, you should first spray on a(n) ______ coat to give the clearcoat something to grab onto.
18. Explain why the painter should spray with, not against, the airflow in the spray booth.
19. A bed side on a pickup truck can be painted in sections or walked. True or False?
20. One painter is spraying a hood. Painting should begin at the center of the hood. True or False?

ASE-TYPE QUESTIONS

1. All of the following are components of spray gun setup EXCEPT:
   (A) fan adjustment.
   (B) distance adjustment.
   (C) material adjustment.
   (D) air pressure adjustment.
2. Technician A says to set the material control first when setting up a spray gun. Technician B says to set the air pressure first. Who is right?
   (A) A only
   (B) B only.
   (C) Both A and B.
   (D) Neither A nor B.
3. A spray fan has a dry center. Which of the following is the most likely cause?
   (A) Too much material.
   (B) Too much air pressure.
   (C) Not enough air pressure.
   (D) Dirty air cap.
4. Technician A says that changing air pressure will affect the fan. Technician B says that spitting is caused by a loose air cap. Who is right?
   (A) A only.
   (B) B only.
   (C) Both A and B.
   (D) Neither A nor B.
5. The painter is not following the contour of the panel. This problem is called ______.
   (A) heeling
   (B) arcing
   (C) banding
   (D) traveling

6. Holding the spray gun too far from the surface causes a ______.
   (A) run
   (B) rough surface
   (C) mottling
   (D) sag
7. Technician A says that gravity causes some flow out on vertical panels. Technician B says that the wetter the paint, the longer the leveling time. Who is right?
   (A) A only.
   (B) B only.
   (C) Both A and B.
   (D) Neither A nor B.
8. Which of the following coats would produce the greatest gloss?
   (A) Mist coat.
   (B) Medium wet coat.
   (C) Full wet coat.
   (D) Drop coat.
9. The roof on a full size van needs to be sprayed. Technician A says to use two painters. Technician B says to paint the roof in sections. Who is right?
   (A) A only.
   (B) B only.
   (C) Both A and B.
   (D) Neither A nor B.
10. Technician A says that an inline air regulator decreases the volume of air delivered to the spray gun. Technician B says that the air pressure should be set without pulling the trigger on the spray gun. Who is right?
    (A) A only.
    (B) B only.
    (C) Both A and B.
    (D) Neither A nor B.
11. A right-handed painter is preparing to spray the left fender of a vehicle in a down-draft spray booth. The painter's right foot should be positioned at ______.
    (A) the middle of the fender
    (B) the front of the fender
    (C) the middle of the door
    (D) the rear of the fender
12. The release of the trigger at the end of the stroke is known as ______.
    (A) arcing
    (B) heeling
    (C) triggering
    (D) banding
13. A pickup truck bed side must be painted. Technician A wants to walk the panel. Technician B wants to paint the panel in sections. Who is right?
    (A) A only.
    (B) B only.
    (C) Both A and B.
    (D) Neither A nor B.
14. A vehicle is to be painted in a down-draft spray booth. Technician A says to spray from bottom to top. Technician B says to spray from top to bottom. Who is right?
    (A) A only.
    (B) B only.
    (C) Both A and B.
    (D) Neither A nor B.
15. A replacement radiator support must be repainted. Technician A says to use a touchup spray gun because it can fit into confined spaces. Technician B says to use a conventional spray gun but to turn down the fan and material. Who is right?
    (A) A only.
    (B) B only.
    (C) Both A and B.
    (D) Neither A nor B.

Chapter 28

Surface Preparation

Objectives

After studying this chapter, you will be able to:

- Understand the importance of proper surface preparation.
- Explain how to clean a panel prior to surface preparation.
- Describe various paint removal processes.
- Explain how to mask for primer and paint.
- List the steps in prepping a scratch, body filler, bare metal, weld, rust, repaint, blend, melt, trim, and aluminum.

Technical Terms

adhesion
appearance weld
back taping
blend
blended panel
bull's-eye
chalking
chemical adhesion
chemical paint stripper
cracking
cutting in
edging
fading
featheredging
flash rust
guide coat
infrared dryer
internal rust
liquid mask
masking plastic
mechanical adhesion
media blasting
melt
nonappearance weld
paint thickness gauge
peeling
pre-paint solvent
pre-sanding solvent
rocker panel spray
sandpaper stripping
scraping
scuffing
seam sealer
shrinkage
stripping
stripping disk
surface rust
tack rag
trimming
UV radiation
weld

Introduction

This chapter explains how to prepare a metal surface for repainting. Surface preparation is an essential part of the refinishing operation. The appearance of the topcoat depends on the thoroughness of surface preparation. A good paint job requires a good foundation, and the surface is the foundation for the topcoat. Attention to detail is critical. Shortcuts, such as improper featheredging or block sanding, will show up in the topcoat.

A full body repaint is rare in the typical collision repair shop. In most repair operations, only part of the vehicle is painted. Surface preparation requires the use of abrasives such as sandpaper, and tools such as grinders and media blasters to ready the vehicle for paint. When using surface preparation equipment, take care not to damage adjacent panels. Often, a repair panel will be next to an undamaged panel. Panels that will not be repainted should be protected. See **Figure 28-1**. Taking proper precautionary measures is always easier than fixing damage. When grinding next to glass, cover it with a welding blanket. This will keep the grinding sparks from damaging the glass.

Adhesion is a term often used in refinishing. ***Adhesion*** is the ability of two substances to bind together. ***Chemical adhesion*** occurs when one substance bonds to another through an interaction between atoms or molecules. A basecoat bonds to sealer through chemical adhesion. In ***mechanical adhesion***, the roughness of a surface allows the liquid topcoat to flow into the tiny grooves and scratches and “grip” onto the surface. For example, when a surface is sanded, the sanding scratches allow mechanical adhesion of the paint.

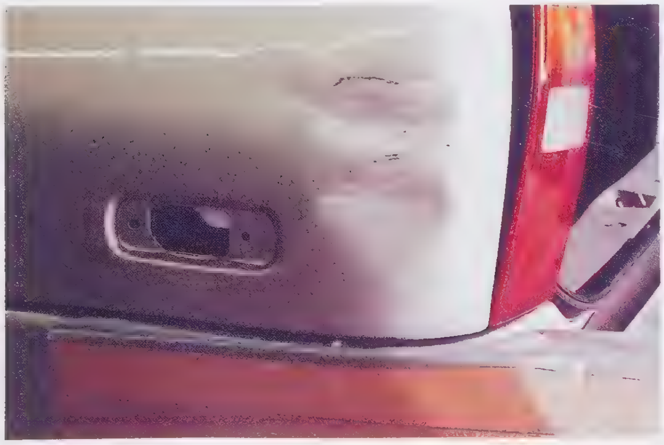


Figure 28-1. *Always take care not to damage adjacent panels. Cardboard and duct tape have been placed to protect the bumper. The taillight will be removed.*

When preparing surfaces for refinishing, always choose the least aggressive method that will do the job. Gouges or scratches created during surface preparation must be fixed later. Sometimes, an aggressive method of preparation is required, such as when preparing a welded panel by grinding away the weld bead. However, if a topcoat needs to be stripped, think twice before using a grinder. Instead, sand with a grade of paper, such as 80-grit, that will cut quickly but not leave deep scratches in the metal surface. Do not make the work any harder than it has to be.

Surface Preparation Standards

There are many ways to prepare a vehicle for repaint. Shop standards dictate the surface preparation procedure. Standards vary, depending on a shop’s goals. For example, a shop that offers a lifetime warranty on paint will usually do more extensive surface preparation than a shop that offers a one-year warranty.

The standards for surface preparation can be divided into three categories: Level 1, Level 2, and Level 3. Level 1 surface preparation requires the least amount of labor. Items such as moldings, weather stripping, nameplates, door locks, handles, and mirrors are masked before painting. All obstructions are left in place unless they are impossible to mask. Because the obstructions are not removed, the paint immediately adjacent to the obstructions cannot be sanded. Also, masking an obstruction will leave an edge of paint. This paint edge will not adhere well to the unsanded paint beneath it and may eventually flake off. When an entire vehicle is not painted, the paint must end somewhere. Existing stripe tape can be used as an edge.

Clearcoat is melted in Level 1 preparation. Melt is another word for a tapering blend. For example, if a quarter panel is painted, the sail panel is prepared for a melt. The clearcoat is sprayed to a thin, tapered edge on the sail panel. This hides the edge of the new paint and disguises the repair. However the thin clearcoat is not durable and will eventually flake off.

The inside, or other side, of bolt-on replacement parts, such as fenders, doors, hoods, deck lids, and hatches, are painted before installation. This is known as 2-step painting. For example, if the quarter panel is replaced, the door opening must be repainted too, so the door opening is prepped, painted, and cured. The door opening is then masked before painting the quarter panel. An experienced refinish technician can look at a Level 1 vehicle and be able to determine that it has been repainted. An average person will not be able to tell.

In Level 2 surface preparation, obstructions are not masked—they are removed. Before a door panel is painted, for example, the interior door trim panel is removed. The technician can then access and remove the mirror, window, moldings, door handle, and keylock. Clearcoat is not melted in Level 2 preparations. If a quarter panel is painted and there is no edge to mask, the roof and opposite quarter panel also will be clearcoated. As in Level 1 preparation, bolt-on replacement parts are painted on the inside before installation. Two-step painting is allowed. Windshield moldings are raised with rope or tape. Level 2 surface preparation requires considerably more labor and attention to detail than Level 1.

The goal of Level 3 surface preparation is to make an undetectable repair. Clearcoat melts are not made. There is no two-step painting. Two-step painting requires that the inner portion of the part, such as the flange of a fender, be masked when the outside of the fender is painted. This will leave a tape edge, an obvious sign of a repaint.

If a quarter panel is replaced, the door is removed and the quarter panel and door opening are painted at the same time. The door is painted off the vehicle at the same time as the quarter panel and door opening. The windshield and back glass are removed, so there are no moldings to mask. The only difference between Level 2 and Level 3 is that in Level 3 painting, the entire part is painted in a single operation. There is no masking edge.

In Level 3 surface preparation, which is even more labor-intensive than Level 2 preparation, bolt-on replacement parts are either painted disassembled and installed, or installed on the vehicle and painted entirely in place. Painting a bolt-on part in place allows the bolt heads to be painted, duplicating a factory appearance.

Basic Surface Preparation Procedures

The following sections describe basic surface preparation procedures. The instructions in these sections apply whether the entire vehicle is refinished or only one panel is painted.

Inspect

Used parts, such as fenders, doors, and hoods, are commonly installed on damaged vehicles. These parts are expected to match new OEM parts in durability and appearance after the repair is complete. Used parts often have problems, such as bad paint or previously repaired damage. Always take the time to carefully inspect used parts.

The surface should be carefully inspected to identify any defects. Examine the vehicle inside the shop, not in bright sunlight. The glare of bright sunlight tends to hide surface defects. Use a ***paint thickness gauge*** to determine the thickness of paint. See **Figure 28-2**. Paint thickness is measured in mils. One mil is 0.001". Take the average of several readings. If the panel is on the upper part of the body and paint thickness is greater than 10 mils, the paint must be stripped. Heating and cooling cycles will fatigue a thick paint film and eventually cause cracking. Due to less sun exposure, paint thickness on lower panels is less critical. Sun induced ***cracking*** begins as tiny slits in the paint surface. As the paint weathers, the slits will grow larger and the paint finish will begin to look dull. At first the cracks are tiny and only visible with a magnifying glass, but with time, the cracks grow and become visible to the naked eye. See **Figure 28-3**. If cracking is present, the topcoat must be removed. Painting over cracked topcoat will cause cracks to show through the new paint.

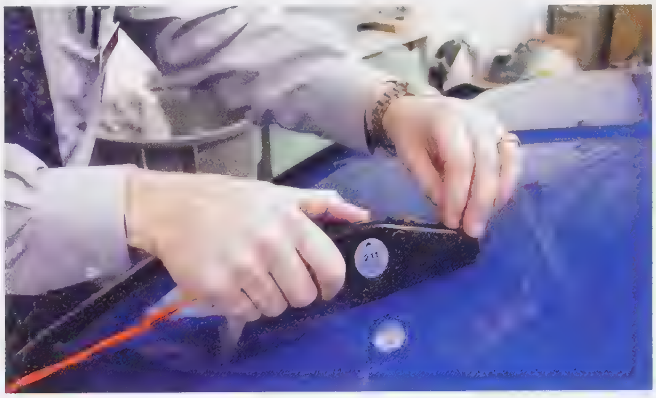


Figure 28-2. *Paint thickness is measured in mils. One mil is 0.001". This paint thickness gauge indicates how much paint is on a steel surface.*

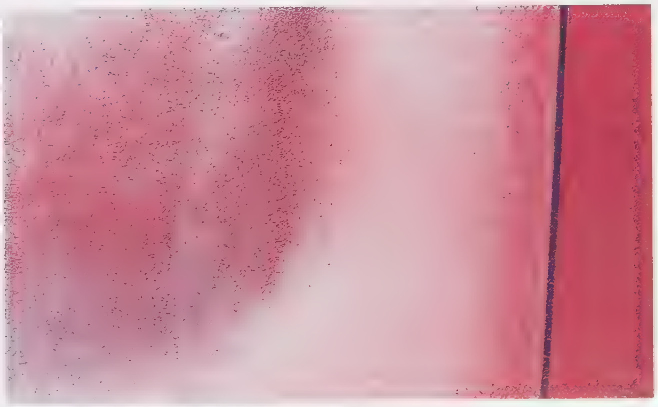


Figure 28-3. *Sun induced cracking begins as tiny slits in the paint surface. If cracking is present, the topcoat must be removed.*

Peeling is caused by loss of adhesion between the topcoat and primer. See **Figure 28-4**. This problem is common on hoods, roofs, and deck lids, as well as the upper portions of fenders, doors, and quarter panels. When a paint film begins to peel, scrape all the topcoat from the panel. Scraping will quickly remove the topcoat. Do not try to featheredge the broken edge of topcoat.

Because different types of refinish paints may be incompatible, you should always determine if the surface has been repainted. Evidence of a repaint includes color mismatch, scratches in paint, and overspray on moldings. **Figure 28-5** shows overspray from poor masking technique. If the surface has been repainted, check paint thickness. If the paint is more than 10 mils thick, it must be stripped off. If more topcoat can be applied, prepare the surface by scuffing the clearcoat. As long as the refinish clearcoat is not sanded through, there should be no problem with compatibility.

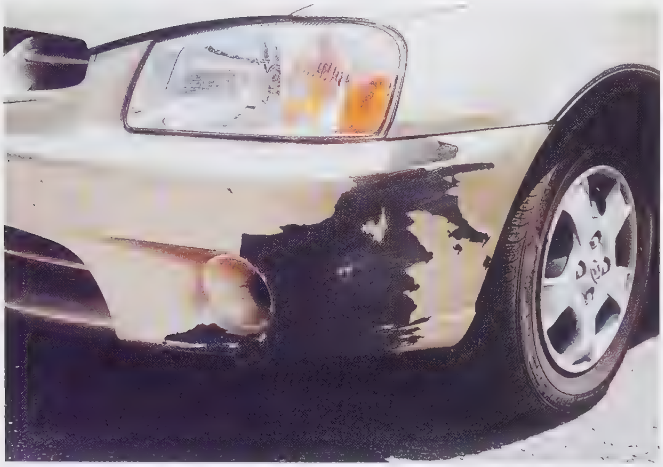


Figure 28-4. *Peeling is caused by loss of adhesion between the topcoat and primer. Remove all the paint from a peeling panel.*

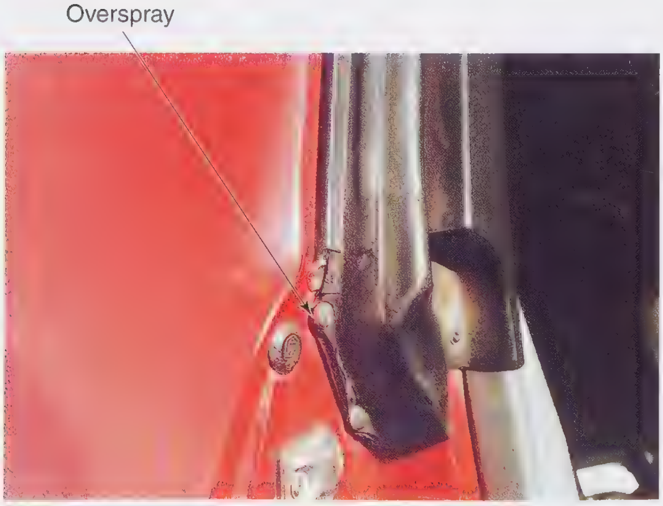


Figure 28-5. *Evidence of poor masking technique. Overspray from a previous repaint is visible on this door window weatherstrip.*

Rust must be identified and dealt with before refinishing a panel. Painting over rust will cause paint failure as the rust will continue to spread underneath the new finish. There are two types of rust: internal rust and surface rust. See **Figure 28-6**. ***Internal rust*** begins on the inside of the panel. See **Figure 28-6A**. As the steel rusts from the inside and corrodes through the panel, the affected area will become weak and bubble-like paint blisters will form on the surface. Probing the rust bubbles will poke a hole through the flakey, rusty steel. Internal rust can only be repaired by cutting out the weakened steel and replacing it.

Surface rust, as seen in **Figure 28-6B**, occurs when the paint on the outside of the panel has been scratched or damaged, exposing bare steel. Steel rusts quickly when exposed to air. Surface rust will look like reddish brown grains. Removal of the grains will reveal

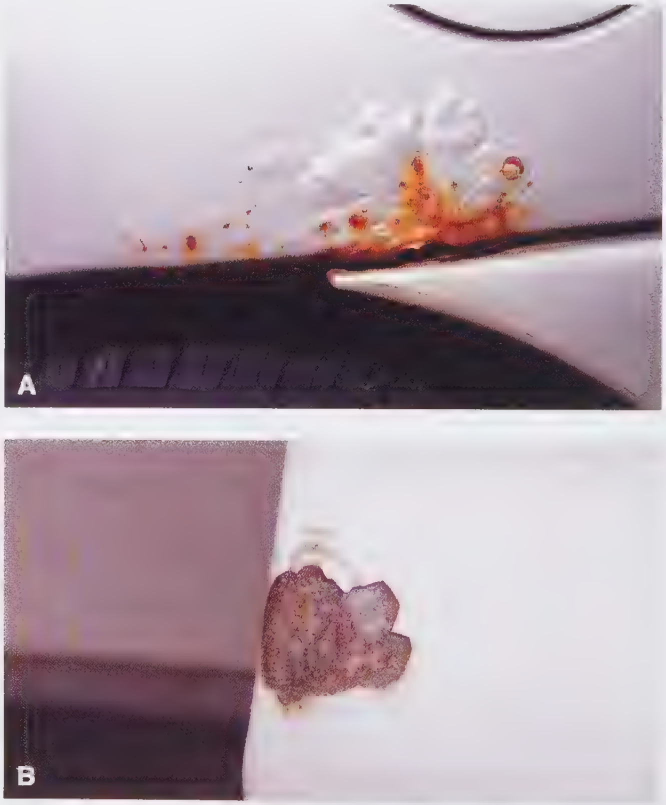


Figure 28-6. *A—Internal rust has discolored the paint on this vehicle. Internal rust starts on the inside of the panel and works to the outside. The metal under the paint is weakened by rust. B—External rust forms on the outside of the panel when paint is damaged, exposing bare metal.*

black pits or corrosion below. These black pits must be removed. Simply painting over the black pits will slow down the rust but will never stop it.

Paint breakdown is caused by exposure to UV radiation, which is present in sunlight. When paint pigment breaks down, the color fades. ***Fading*** is a gradual change in the color, **Figure 28-7**. To check for fading on a single-stage paint, apply rubbing compound to the surface. The mild abrasive in the rubbing compound will remove the upper layer of paint. If the paint is brighter after rubbing, the paint has faded. On a basecoat/clearcoat paint, open the door, or trunk, or any other area not usually exposed to the sun and compare it with the outside paint. A difference in color indicates that the outside paint has faded. Paint fade is an important consideration when color matching.

Paint binder breakdown causes ***chalking***. Chalking paint is so weather-beaten that it has no gloss and can be brushed off as a dry powder. See **Figure 28-8**. Because binder, the backbone of the paint, has deteriorated, all chalking paint should be removed.

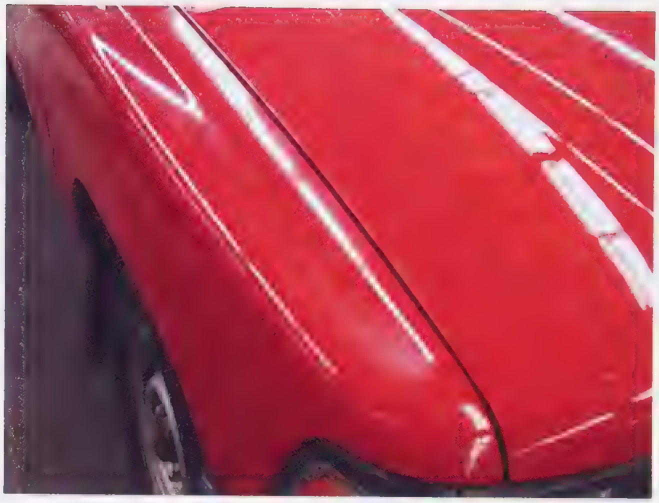


Figure 28-7. *Fading is caused by exposure to UV radiation. Buffing the hood restored some of the shine, but the fender, which was not buffed, is still dull.*

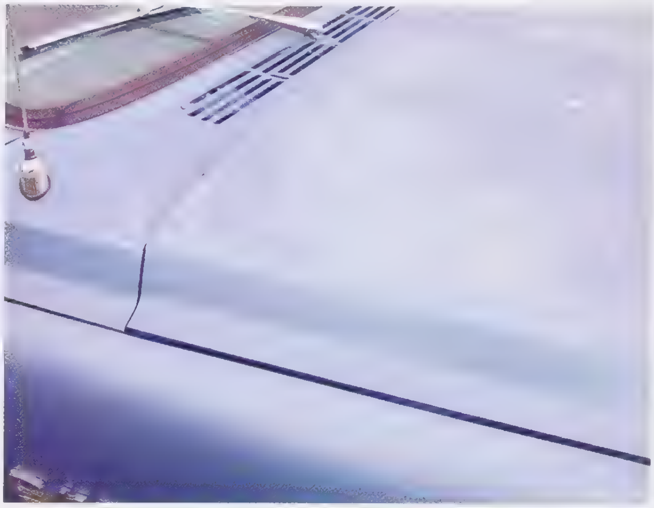


Figure 28-8. *Chalking paint is so weather-beaten that it has no gloss and can be brushed off as a dry powder. All chalking paint should be removed.*

Plan

The first aspect of planning is to determine which panels will be painted, blended, or melted. Painted means the entire panel will be sprayed with basecoat and clearcoat. A ***blended panel*** is partially sprayed with basecoat but entirely sprayed with clearcoat. In a melt, the panel is partially sprayed with basecoat and clearcoat.

Blending hides a slight mismatch between the original color and the refinish paint. If an entire panel will be painted, all panels adjacent the panel will be blended. For example, if a new left fender is installed on a four-door vehicle, the fender will be painted and the hood, front bumper, and left front door will be blended.

If a panel is repaired, it can be blended if the repair area is at least 6" away from any panel edge. This extra space will allow enough room for a blend to hide a color mismatch. If the undercoat is within 6" of the edge of a panel, the adjacent panel should be blended. For example, a 4-door vehicle has a dent in the right rear door. The dent is repaired and the undercoat applied to the rear door repair is 2" from the front edge of the door. The repair is closer than 6" from the edge of the door and therefore, the front door should be blended. The quarter panel does not need to be blended because, in this example, it is more than 6" away from the newly applied undercoat on the rear door.

The next aspect of planning is to decide how much labor will be required to prepare the panels for refinishing. For example, if a used door will be installed and the inspection shows that the door has cracked paint, the paint must be removed. If internal rust is found on a used part, the rusted area must be repaired before painting. This additional work will require more time, and the total amount of time needed to complete the repair must be accurately estimated.

Repairs of external surfaces may damage internal surfaces. In these cases, surface preparation must include not only the outside of the panel, but the inside as well. For example, to repair a dent in a door, draw pins may be welded onto the outside of the panel to pull out the damage. The heat generated during welding will burn the antirust coating off the inside of the door.

In this example, the door must be disassembled for access to the inside of the panel. The burned paint is sanded down and the area is either retreated with rust proofing, or sprayed with epoxy primer or self-etching primer. In another example, damage to a quarter panel may break open a panel seam inside the trunk. Seam sealer must be reapplied to prevent water damage inside the trunk. Always consider internal repairs when planning.

The final aspect of planning is to decide where the refinishing will end. Because the entire vehicle is usually not refinished, the painting or blending will always have an edge. A vehicle is made of separate panels, such as fenders, hood, and doors. The vehicle also has joined panels, such as the roof and uniside or quarter panel, and the quarter panel and rear body panel. See **Figure 28-9**. A separate panel makes a good edge. Simply mask off panels that will not be sprayed, blend the basecoat, and then apply the clearcoat to the entire panel. Joined panels such as the junction between a roof and sail panel are blended and clearcoated.

To save labor, entire panels or joined panels are not completely refinished. For example, if the vehicle has a uniside and the quarter panel is dented, the edge of the refinish is the roof/uniside joint. The seam between the roof and uniside is masked, the quarter panel repaired damage is sprayed with basecoat, and the quarter panel and uniside above the doors are clearcoated. Some shops using Level 1 surface preparation will mask on a tape stripe to form an edge. If a new hood is installed and painted, the fenders will be blended. If the vehicle has a tape stripe that extends along the entire fender, the stripe can be taped and the fenders blended between the hood and the tape stripe. This is less labor intensive than preparing the entire fender for clearcoat, and the stripe tends to hide a slight mismatch in color because the stripe is a natural border.

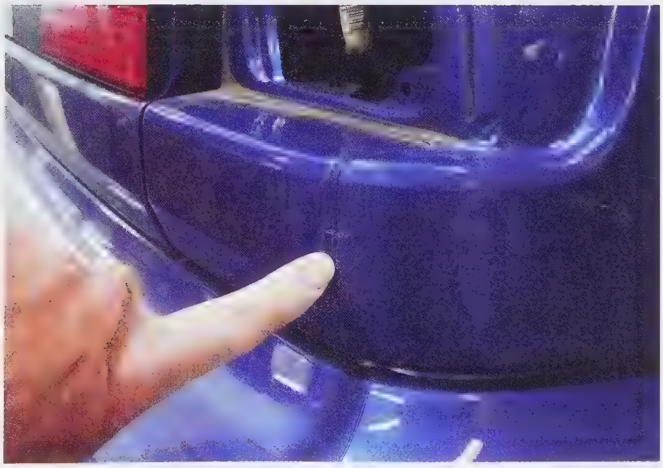


Figure 28-9. *Part of the planning process is deciding where the refinishing will stop. This seam sealer filled joint between panels makes a good edge, and an excellent place to stop painting.*

Wash

The entire vehicle should be washed with soap and warm water before starting paint preparations. A clean vehicle is the first step to a quality paint job. Some contaminants, such as dried mud and road salt, are water based and easily removed with soap and water. If the vehicle has a lot of mud on it, common in four-wheel drive trucks and SUVs, take the time to rinse off or pressure wash the vehicle before washing with soap and water.

Remove Obstructions

If the shop's policy dictates that all obstructions are removed before repainting, the following recommendations will apply. If shop policy requires that only the basic obstructions be removed, follow only the pertinent recommendations.

Glued-on moldings can be removed with an air chisel and a molding removal blade. Some moldings are attached with clips. To remove this type of molding, the molding is pushed up or down, unlocking the molding from the clip. The molding can then slide off. Removal of many door-based obstructions, such as the mirror, key lock, door handle, and belt molding requires door panel removal. These obstructions are bolted on from inside the door. Usually, the door glass must be removed for access to the door handle and key lock. Remove the door glass run channel after the door glass has been removed.

Tape stripes and decals can be removed with a stripe eraser. The eraser will not damage the underlying paint. Use a drill or cutoff tool to power the stripe eraser. Keep the stripe eraser on the stripe or decal and work up and down. See **Figure 28-10**.

NOTE

The best way to prepare a vehicle for paint is to remove all obstructions.

Pre-Sand Cleaning

Proper surface preparation requires a thorough cleaning of the surface. If wax or other surface contamination is not removed from the surface before sanding, the contaminants will be driven into the surface during

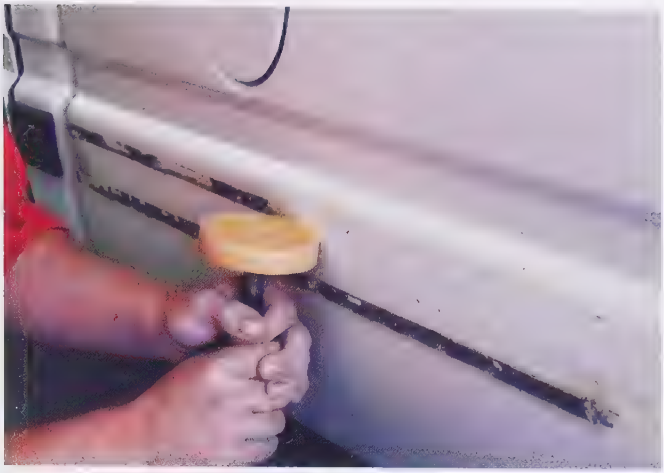


Figure 28-10. *The stripe eraser will not damage the underlying paint while removing adhesive, decals, or stripe tape.*

the sanding operation. These contaminants, such as silicone or wax, will not allow paint to adhere. The contaminated areas will show up as fish eyes in the newly applied paint.

A ***pre-sanding solvent*** is used to dissolve oil-soluble contaminants, such as wax, grease, and tar. Solvent can be applied with a spray bottle as shown in **Figure 28-11**. Spray the solvent on the panel and then wipe it dry with a clean paper towel. Another method is to soak a towel in solvent, wipe down the surface with the solvent-soaked towel, and then dry the surface with a clean towel. In either operation, the solvent must not be allowed to dry on the surface. Wipe the solvent off while it is still wet. Surfaces that are badly contaminated can be cleaned by first soaking a towel with solvent and then laying the towel on the surface for two to three minutes. This will allow the solvent to soak into and dissolve the contaminant. Always wear gloves when handling solvent.

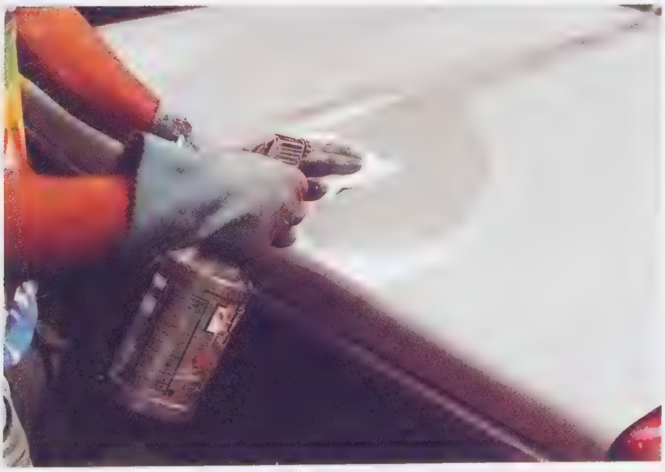


Figure 28-11. *Spray pre-sanding solvent on the panel and wipe it dry with a clean paper towel. The solvent must not be allowed to dry on the surface. Wipe the solvent off while it is still wet.*

Paint Removal

Some degree of paint removal is required for refinish paint to adhere to the existing paint. Paint removal can be so aggressive that all the paint is removed or so mild that the existing paint is simply dulled. Various paint removal processes will be discussed in the following sections.

Stripping

Stripping involves removing all paint from a surface, leaving the metal bare. Paint can be stripped by chemical stripping, media blasting, or sanding.

Chemical paint stripper should be used on paint that melts when sanded, such as lacquer. This type of paint tends to clog sandpaper. A chemical stripper will soften and loosen any paint on any surface. If only one panel on a vehicle is to be stripped, the panel should be removed from the vehicle, if possible. This will minimize the chance of damaging adjacent panels. If the panel to be stripped cannot be removed, protect the adjacent surfaces with cardboard covered with plastic sheeting.

- Chemical stripper works best at temperatures above 75°F (23.8°C). Wear impervious gloves and eye protection, and work in a well-ventilated area. Follow any mixing directions on the stripper container, and apply the stripper with a brush. Once the stripper is applied, do not brush over it. Upon application, the stripper forms a seal on the surface to prevent evaporation of the active agents. Breaking this seal by brushing over it again allows the active agents to evaporate, diminishing the effectiveness of the stripper. Masking plastic can be placed over the panel to cover the stripper. The plastic prevents evaporation, giving the stripper more time to work. Allow the stripper enough time to soften and blister the paint. Scrape the loosened paint with a plastic putty knife. See **Figure 28-12**. Additional applications of stripper may be required if the panel has several layers of paint on it. After scraping, remove all traces of paint and stripper by washing the surface with water. Be sure to remove all the stripper. Any stripper left behind will react with the new paint.
- ***Media blasting*** involves the use of compressed air to power (blast) an abrasive material (media). The media can be sand, silicon carbide, aluminum oxide, plastic beads, powder, or even walnut shells.

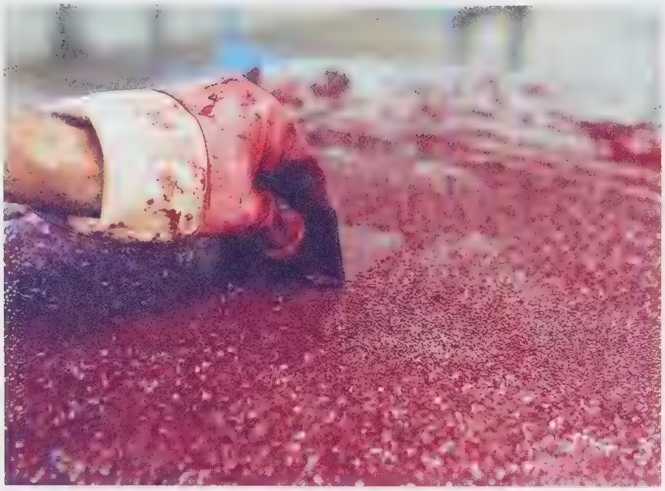


Figure 28-12. *Paint stripper works best at temperatures above 75°F (23.8°C). Allow the stripper enough time to soften and blister the paint. Remove the loosened paint with a scraper.*

Media blasting with sand, silicon carbide, or aluminum oxide removes paint quickly, but the aggressive media will pit and possibly distort the sheet metal. This type of blasting is not the best way to remove all the paint from a vehicle, because the process can easily generate enough heat to warp a low-crown panel. In auto body repair, aggressive blasting should be confined to cleaning before and after welding and cleaning rusty metal. A hand-held captive blaster, shown in **Figure 28-13**, uses silicon carbide or aluminum oxide media. This tool captures the spent abrasive for reuse. Larger types of captive media blasters are available. To use one of these media blasters, push the end of the blaster against the panel, pull the trigger for a few seconds, and then pull the blaster away from the panel.

Soft media, such as plastic beads or powder (baking soda), is the preferred way to strip paint in auto body applications. This media does not create as much heat as more aggressive media. Paint removal is slower because the soft media is not as aggressive as sand, aluminum oxide, or silicon carbide. Paint can be removed layer by layer, which is a big advantage if only the topcoat needs to be removed. Soft media blasting is usually done by specialty shops.

Sandpaper stripping is shown in **Figure 28-14**. On a vehicle with OEM paint only, stripping can be done with 80-grit sandpaper on a dual-action sander. Repainted vehicles can be stripped with a buffer and 24- or 36-grit sandpaper mounted on a 7" grinder disk. The buffer's larger disk removes paint from a larger area than the smaller disk attached to a grinder. This is an effective way to remove paint. Be sure to protect adjacent surfaces with duct tape and cardboard.

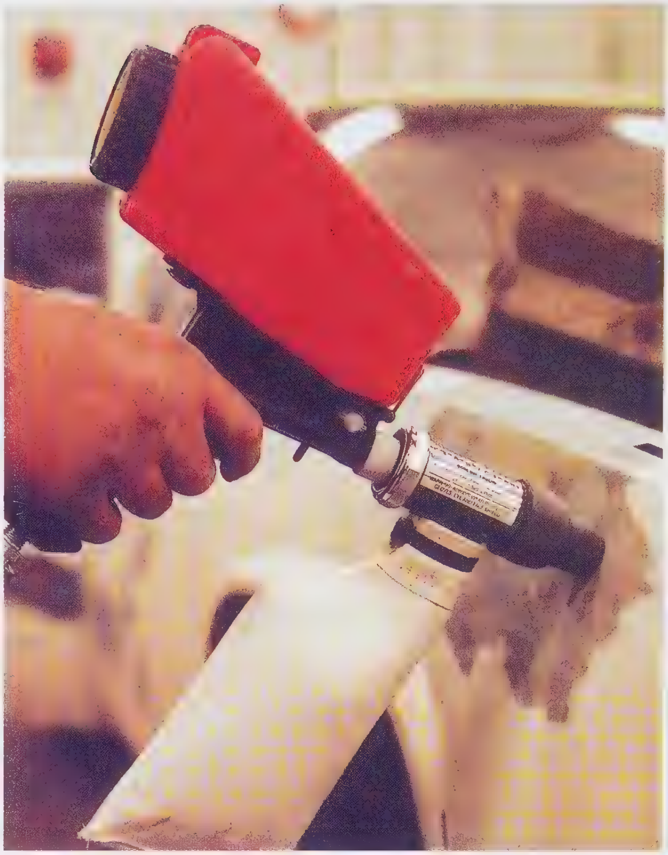


Figure 28-13. *A hand-held captive sand blaster removes paint and rust from a small area.*

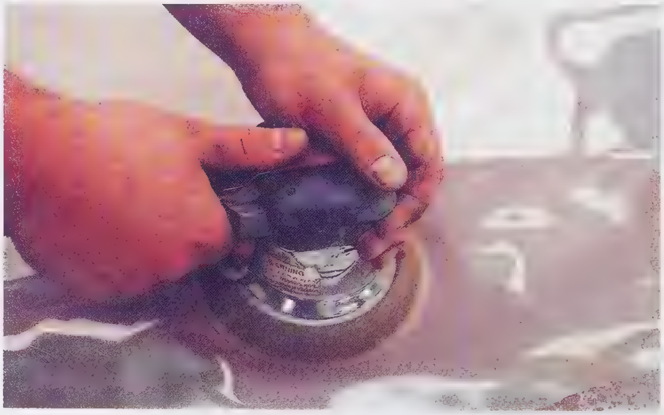


Figure 28-14. *A dual-action sander and 80-grit sandpaper is a fast and effective way to strip paint.*

Keep the sander moving to minimize heat buildup. Do not sand in any one area for more than a few seconds. This is especially important on low-crown panels. Once the paint is removed, stop sanding. Do not remove metal. If the disk becomes clogged with melted paint, stop the disk and tap it with a screwdriver to knock off the paint. If the paint cannot be removed or the grit on the disk is dull, replace the disk.

A ***stripping disk*** will remove paint with a minimum amount of damage to the underlying metal. It is made from a scuff pad type of material. To strip with a stripping disk, hold the buffer at a slight angle and watch as the paint is removed. Constantly move the buffer around to minimize heat buildup. The stripping disk will gradually clog with paint and wear down with use. Replace the stripping disk when it no longer removes paint. A clogged disk will generate excess heat, which may cause a low-crown panel to warp.

Partial Paint Removal

In partial paint removal, only a portion of the paint on a surface is removed. ***Scraping*** is an efficient way to remove a peeling topcoat. It is done with a razor blade and holder. The angle between the blade and the surface is important. When the angle is correct, the length of a panel can be scraped in a single pass. Start where the paint is peeling and work out from that point. Usually, a panel can be scraped in less than 30 minutes. The challenge when scraping is to avoid putting scratches into the undercoat. Scraping over a body line can cause the razor blade to grab into the body line, causing a gouge. The corners of the razor blade should be filed to minimize scratching. If the topcoat is properly scraped off and the undercoat is still good, the undercoat can be sanded, sealed, and topcoated. If the undercoat is in poor shape and peeling, or if the undercoat is scratched during topcoat removal, additional preparation is needed. **Figure 28-15** shows how effective scraping can be.

Sanding can be used for partial paint removal when an entire vehicle is to be repainted. New paint adheres to a surface mechanically by grabbing into tiny ridges and valleys in the surface. Sanding creates those ridges and valleys and effectively doubles the contact area. Sanding should be done with 220–320-grit sandpaper. OEM paint on the vehicle is sanded with 320-grit paper. Sanding is usually done with a dual-action sander or other power sanding tool. Sanding OEM paint with a DA sander is shown in **Figure 28-16**. Hold the DA flat to prevent digging in and gouging the surface. A sanded surface should be coated with a surfacer or sealer to fill the sanding scratches created before the new topcoat is applied. Surfacer or sealer will fill in the 320-grit scratches; basecoat will not. If basecoat is sprayed over 320-grit scratches, the scratches will be visible in the clearcoat.

NOTE

If the basecoat/clearcoat paint on a used part is in good shape and not too thick, the clearcoat can be sanded before the application of the sealer and topcoat.

Scuffing is also used to put ridges and valleys into a paint surface. However, unlike sanding, scuffing uses very fine sandpaper and does not require a sealer or surfacer to fill scratches. In most cases, 600-grit or finer sandpaper is used for scuffing. Scuffing can also be done with an abrasive pad. The purpose of scuffing is to remove the shine from the paint surface. Removing the shine, or dulling the surface, will provide enough ridges and valleys, or tooth, to allow the new paint to adhere properly.

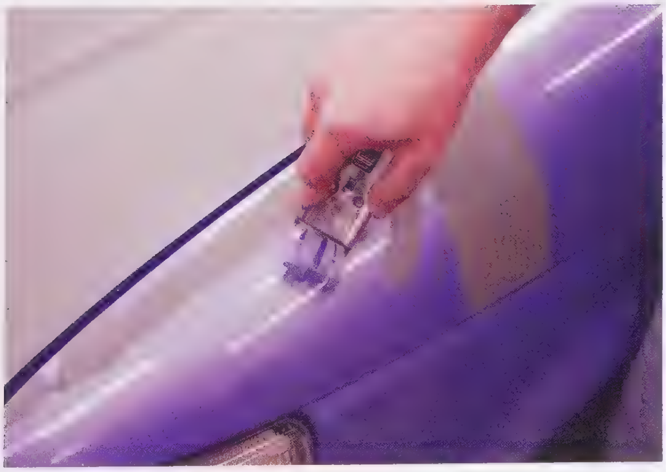


Figure 28-15. *Scraping is an efficient way to remove a peeling topcoat. It is done with a razor blade and holder. A panel can be scraped in less than 30 minutes.*

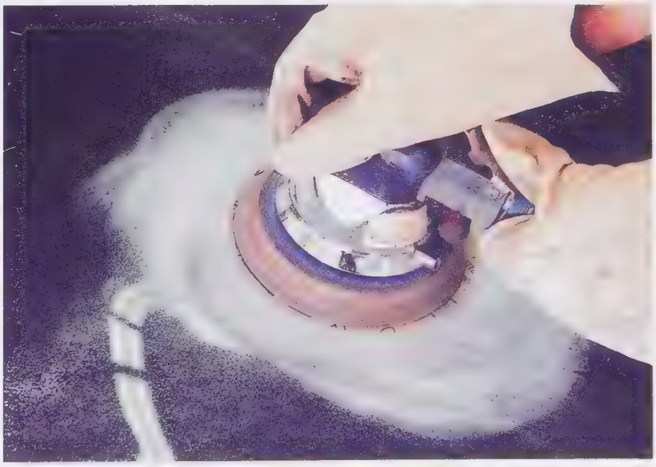


Figure 28-16. *Hold the DA flat to prevent digging in and gouging the surface. Holding the sander at an angle will dig a groove into the paint.*

Scuffing can be done dry, either by hand or with a DA sander. It can also be done wet with a sanding pad, or damp with a DA sander. Careful scuffing will provide for good paint adhesion. Careless scuffing will leave shiny spots. If the shiny spots are painted over, the new paint will not adhere properly, leading to peeling problems. Proper scuffing is especially important around moldings and obstructions. See **Figure 28-17**.

Proper ***featheredging*** is essential for an invisible repair. Featheredging produces a gradual taper of the paint edges around a repair. See **Figure 28-18**. Three grits of sandpaper are used for featheredging: 80-, 180-, and 320-grit. Always keep the sandpaper flat against the broken paint. A dual-action sander is the first choice for featheredging, but a sanding block can be used. Begin by using the 80-grit paper to remove any scratches and to flatten the paint edge. There should be 1/2" of each paint layer exposed after using the 80-grit paper. Switch to 180-grit to remove the 80-grit scratches. Finally, switch to 320-grit paper to remove the 180-grit scratches. Extend the 320-grit sanding at least 2" away from the edge of the upper paint layer. This is to promote adhesion of the surfacer around the featheredged area. The surfacer should be applied within the sanded area. The surfacer will fill the depression and be block sanded flat.

Often, the location of an obstruction will not allow enough room for a proper featheredge. The obstruction could be a molding, a stripe, or weather stripping. Remove the obstruction instead of reducing the featheredged area. **Figure 28-19** shows correct featheredge technique.

Masking for Undercoats

Masking will keep paint off surfaces where it does not belong. Proper masking minimizes cleanup time. Masking for primer is intended to protect surrounding surfaces from overspray. This type of masking is intended to be fast and only elaborate enough to prevent damage. It will all be removed before block sanding.

Masking begins on the inside of the vehicle and proceeds to the outside. Overspray can enter through panel gaps, so the inside surfaces of doors, hoods, and deck lids should be protected. If masking tape is applied to a surface and paint is sprayed over the masking tape, a visible edge will remain in the paint when the tape is removed. On inside surfaces, ***back taping*** can prevent the visible line problem. When back taping, the edge nearest the area to be painted is rolled back, **Figure 28-20**. This feathers the overspray, tapering the paint edge and making it less visible. If painting will end at a raised edge, such as a tape stripe or body seam, do not apply undercoats up to the raised edge. If undercoats

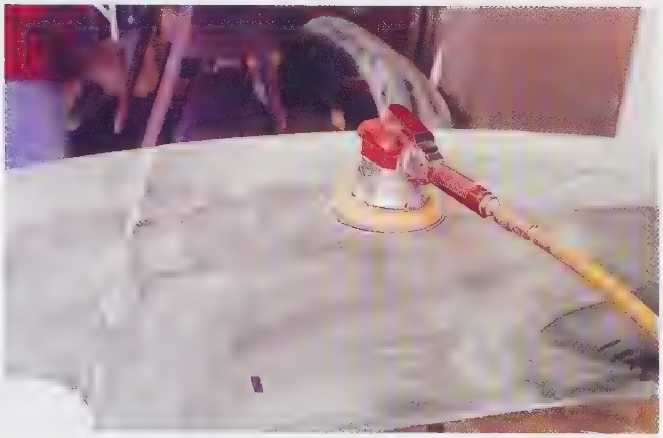


Figure 28-17. *The purpose of scuffing is to remove the shine from the paint surface. Dulling the surface will provide enough "tooth" to allow the new paint to adhere properly.*

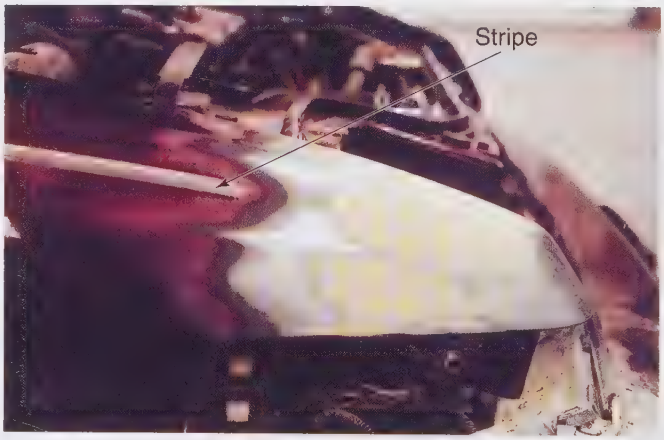


Figure 28-19. *Remove the obstruction instead of reducing the featheredged area. Notice the stripe has not been removed. The stripe should be removed and the paint underneath it featheredged.*

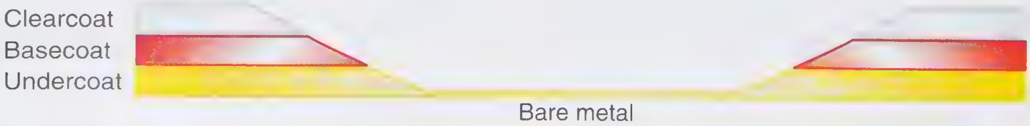


Figure 28-18. *Featheredging gradually tapers the paint edges around a repair. Surfacer will fill the depression and be block sanded flat for an invisible repair.*

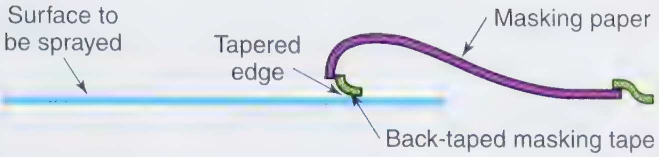


Figure 28-20. *Back taping is used to eliminate the hard, visible edge of paint caused by masking tape.*

were applied to the raised edge and then painted over, the refinish undercoat and topcoat would be too thick along the raised edge. Mask the raised edge so only topcoat, not undercoat, is applied next to it.

If only part of the panel is to be sprayed, apply 18" masking paper around the repair area. Back tape 2" masking tape within the sanded area. The ***back taping*** will keep undercoats off areas that have not been sanded. Tear the masking paper from the masking tape machine by pulling from the masking tape side. Tape the paper to the 2" masking tape as shown in **Figure 28-21**. Then tape the other end of the paper to the vehicle. After masking around the repair area, mask the remainder of the vehicle with a plastic sheet as shown in **Figure 28-22**.

Undersurfaces, such as the wheel wells, frame, and suspension components, can be protected from overspray with ***liquid mask***. The liquid mask is applied with a spray gun and dries to form a protective film. It also locks dirt in place, keeping it out of the wet paint. After painting, the film is removed by washing.

The masking can be left in place to protect the vehicle from sanding dust and sanding sludge, or the masking can be removed after the undercoat has been applied. Be careful around wet paint. Removing the masking when the paint is still wet can lead to accidents, such as tape or paper falling into the wet paint.

When masking an irregular area, sheets of wide aluminum foil can be used. The foil can be firmly crimped into place and not be blown around by air discharged from the spray gun.

Figure 28-23 shows a panel that has been masked for undercoat; other panels are similar. Remember the following rules about masking:

- Remove as many obstructions as practical.
- Work from inside to outside.

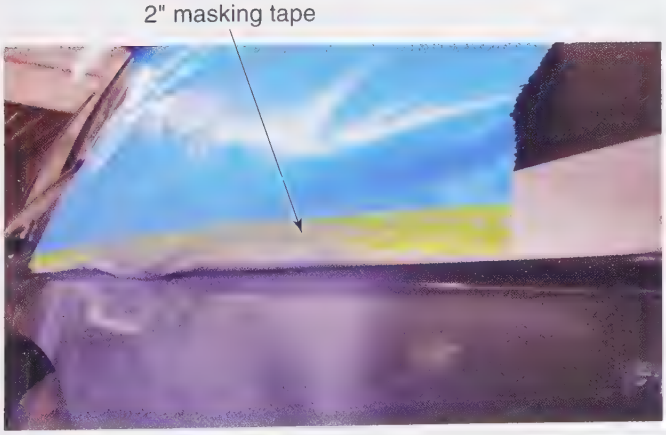


Figure 28-21. *The 2" masking tape has been back taped on a body line to create a soft edge for undercoat application.*

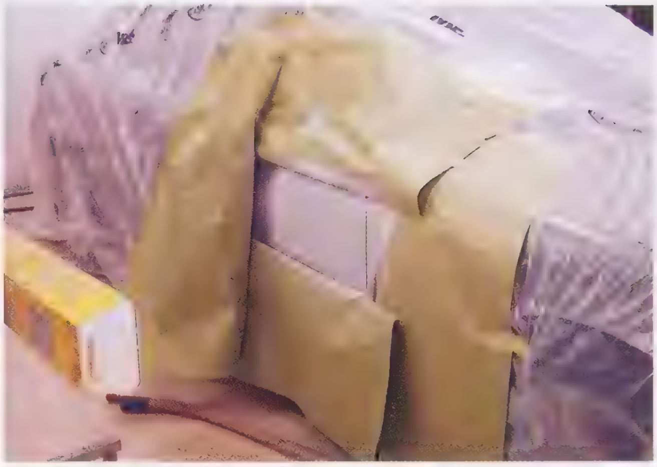


Figure 28-22. *Plastic sheet protects the rest of the vehicle from overspray. Make sure that the plastic sheet is oriented properly and not upside down.*

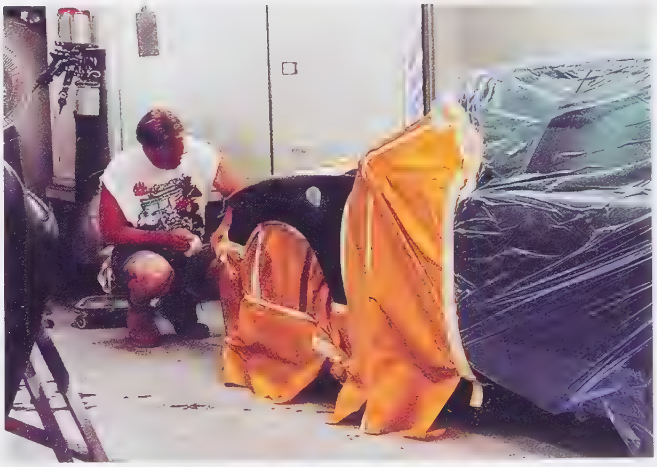


Figure 28-23. *The fender will be sprayed with undercoat. The panels adjacent to the fender are masked with 18" masking paper. The rest of the vehicle is covered with plastic sheeting.*

- Wash and blow off panels before paint masking.
- Open creases in masking paper can trap contaminants, so tape over all folds. See **Figure 28-24**.
- Proper masking will minimize the amount of time spent on cleanup.

Metal Conditioning

Bare metal must be treated if the undercoat is to adhere properly. One way to accomplish this is to use an acid wash followed with a phosphate coating. The acid is contained in a solution called metal prep. The phosphate coating is often called a conversion coat.

NOTE

Self-etching primer can be used in place of the acid wash and conversion coating. Using self-etching primer is less work than cleaning and phosphate coating.

When bare metal is exposed to air, it will almost instantly begin to rust as it reacts with the moisture and oxygen in the air. This invisible layer of rust is known as ***flash rust***. Once rust starts, it never stops growing. To eliminate flash rust, bare metal can be treated with an acid wash. The acid is mixed in a ratio of 1 part acid to 2 parts water. Mix it in a plastic container, wear rubber gloves, and work in a well-ventilated area. Use the spray bottle to wet the bare metal surface as shown in **Figure 28-25**. The bare metal should be kept wet for approximately 5 minutes. If the surface has visible rust, use an abrasive pad to work the acid wash into the rust. Do not allow the acid wash to dry on the surface. After five minutes, the acid wash can be wiped off. Avoid applying acid wash over body filler or paint. Do not acid wash an area and then apply body filler over the treated area.

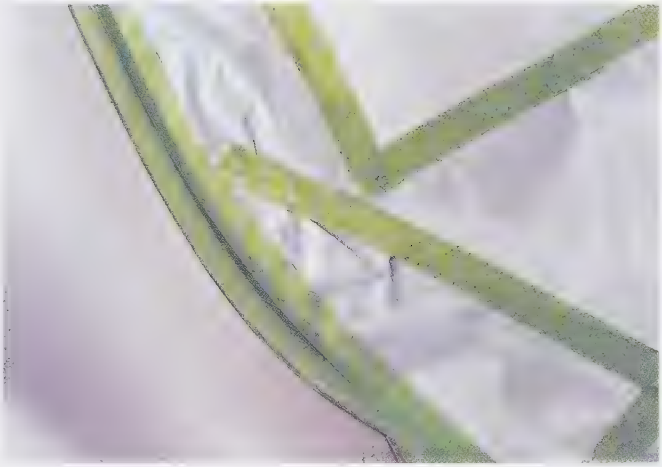


Figure 28-24. *Creases and folds can trap dirt and dry overspray. Tape over all folds or creases. This is especially important when masking for topcoat.*

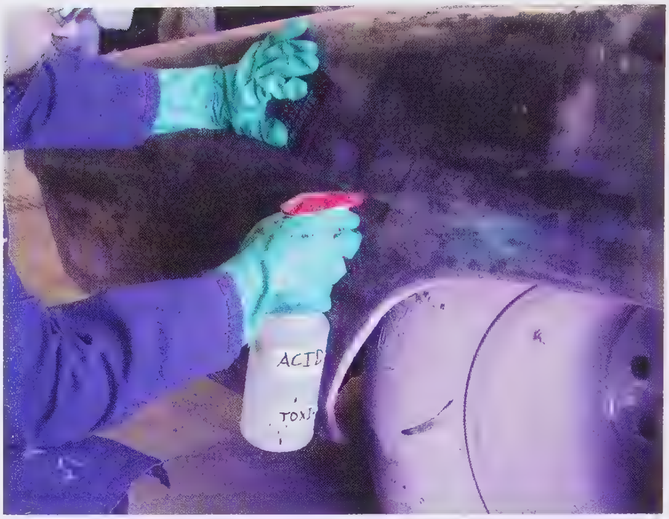


Figure 28-25. *To eliminate flash rust, bare metal can be treated with a phosphoric acid wash. Here, a spray bottle is used to wet a panel with acid wash. If the surface has visible rust, use an abrasive pad to work the acid into the rust.*

Phosphate coating allows for a good bond between the bare metal and the surfacer. Apply the conversion coating to the acid washed bare metal in the same way as you apply the acid wash. Keep the surface wet for approximately 5 minutes. Reapply if the surface dries out. After 5 minutes, rinse the coating off with water and wipe the surface down with a clean, dry cloth.

Apply Undercoats

The undercoat is the foundation for the topcoat. Any shortcuts taken in preparing for and applying undercoats will show up later as defects in the topcoat. Some of these defects, such as fish eyes and sand scratch swelling, will show up during painting. Others, such as bull's-eyes and scratches, will show up after the paint has cured for several months.

Set the spray gun fan to match the size of the area to be sprayed. The small fan minimizes the amount of overspray on adjacent areas; a large fan gives maximum coverage. If the repair is a small area, such as 4" × 4", adjust the pattern control knob for a small fan. For a whole panel, such as a door, set the fan at maximum. After setting the fan size, set the material control so enough paint is in the fan to wet the surface. Finally, adjust the air pressure to the value specified by the paint manufacturer. Apply wet coats and observe the recommended flash time. Always spray within the sanded areas. Do not spray over an area that has not been sanded or scuffed, as the paint will not stick.

Primer

A primer binds to bare metal. The two types of primer used in automotive refinishing are self-etching primer and epoxy primer. Self-etching primer contains an acid and will treat bare metal. Do not apply body filler or seam sealer over self-etching primer. These materials are not compatible with the primer, and an adhesion problem will result.

Epoxy primer binds to conditioned metal. The bare metal must be treated with acid wash and a phosphate coat before application of epoxy primer. The only exception is if the paint on the panel was in good shape and metal under the paint has been bare for less than 1 hour. Epoxy primer can be applied to bare metal and body filler can be applied over it. This helps prevent rust formation under the filler.

When body filler and bare metal are present, apply the self-etching or epoxy primer to the bare metal. Although the primer can be sprayed over the body filler, it is not required. Check the manufacturer's recommendations for the number of coats and the flash time between coats. Also, observe the required cure time before applying surfacer.

Surfacer

Surfacer is used to fill small scratches in the primer surface. Urethane surfacers, mixed with a hardener, commonly called 2K, can fill 180-grit scratches. Scratches deeper and wider than those made with 180-grit abrasive, such as those made by 80-grit sandpaper, may appear to be filled at the time the vehicle is painted, but the surfacer may shrink as it cures and expose sanding scratches in the topcoat weeks or even months after the vehicle is painted.

Surfacer must be mixed properly to flow into and completely fill scratches. It is wrong to think that thicker surfacer, mixed by leaving out some or all of the reducer, will fill better than properly mixed surfacer. Thick surfacer cannot flow into and fill the scratches. Instead of completely filling sanding scratches, the thick surfacer bridges over the scratch, leaving a hollow void below. As the surfacer cures, a process that may take weeks, the surfacer and topcoat will sink into the void causing an outline of the scratches to appear in the finished paint.

Always block sand body filler with 180-grit sandpaper before applying surfacer. Spray surfacer within the area that was featheredged with 320-grit sandpaper. This will ensure that the surfacer is applied only to sanded areas. See **Figure 28-26**.

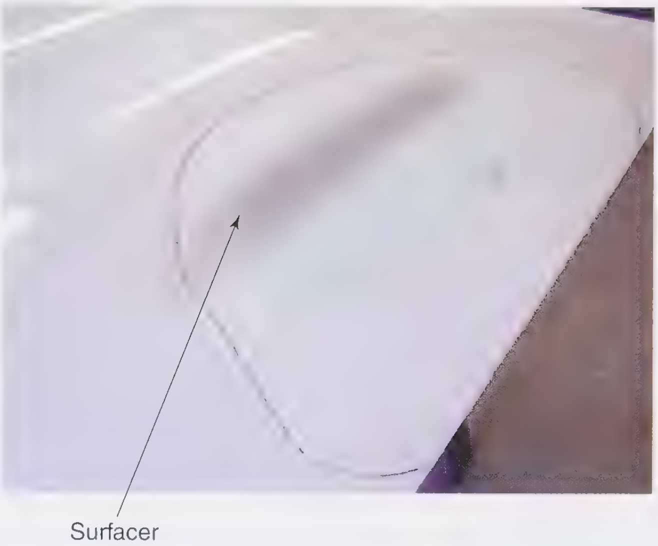


Figure 28-26. *After featheredging with 320-grit sandpaper, surfacer will be sprayed within the outlined area. One stroke of surfacer has already been applied. Notice the narrow fan.*

Apply one coat of surfacer for every layer of paint showing in the featheredge. However, do not apply more than four coats. Follow the manufacturer's recommendations for flash time between coats. Spraying the coats too soon will not allow all the solvent to escape. This will lengthen the cure time.

There is a limit to the surfacer's ability to fill. For example, some vehicles have an exceptionally thick undercoat. Featheredging this thick undercoat will create a deeper than usual depression, which would require multiple, heavy coats of surfacer to fill. As the heavy application of surfacer shrinks while curing, it pulls the topcoat with it, resulting in a paint defect known as a ***bull's-eye***. To prevent this problem, apply two-part spot putty over epoxy primer instead of surfacer. Do not apply the two-part spot putty to the basecoat or clearcoat in the featheredge, only the undercoats. Allow the two-part spot putty to cure and sand with 80-, 180-, and 320-grit sandpaper. When sanding with 80- and 180-grit sandpaper, sand only on the spot putty, not the surrounding paint. Featheredge the spot putty into the surrounding paint with 320-grit sandpaper on a block. Apply three coats of surfacer to the block sanded two-part spot putty. Keep surfacer application within the 320-grit sanded area.

NOTE

If you anticipate the need for spot putty, then epoxy primer should be used instead of self-etching primer.

Sealer

Sealer is often sprayed over surfacer to provide a uniform color for the basecoat. Sealer can be tinted to match the basecoat, or it may be mixed to a specified shade of gray. Tinting the sealer or mixing the specified shade of gray allows the sealer to be covered with fewer coats of basecoat. This saves money, as sealer is less expensive than basecoat. Sealer can also serve as an adhesion promoter on new replacement parts. Some shops scuff, sand, and spray sealer on bolt-on replacement parts that will be painted with basecoat/clearcoat.

Undercoat Curing

Automotive paint cures by solvent evaporation and/or isocyanate crosslinking. The rate of solvent evaporation and isocyanate crosslinking can be accelerated by heat. Increasing the temperature of wet paint to 120°–140°F (48.8°–60°C) accelerates the rate of cure. Air curing means that the temperature of the wet paint will not be higher than 75°F (23.8°C). For isocyanates to crosslink, the paint temperature must be at least 60°F (15.5°C). Solvent evaporation can also be enhanced by increased airflow. A spray booth pulls air across the wet paint. This is why paint cures faster in a spray booth.

Curing may take up to three hours. Sanding the surfacer before it has cured will load the sandpaper with bits of uncured resin. Painting improperly cured surfacer will cause shrinkage and sanding scratches. Heat curing the surfacer can be done with infrared drying equipment or heated air, such as a baking spray booth.

An ***infrared dryer*** pointed at a panel raises the temperature of the paint in that one spot. It also cures by heating the surrounding air and raising the temperature of the entire vehicle. Infrared drying can cure paint in 10 minutes. Usually, the undercoat is allowed to flash off before the heat is applied. Allow the surface to cool down naturally before sanding.

Undercoats that cure by ***UV radiation*** can cure in less than 5 minutes. All UV-cure paints can be cured with a UV lamp, although there is one paint manufacturer that allows the sun to be the source of UV radiation. The UV lamp must be set at a specific distance from the surface and must shine directly on the paint to cure it. Paint shaded from the UV rays by a protrusion, such as a side mirror, will not cure. The lamp must be moved and repositioned to ensure that all the undercoat is exposed to UV radiation. Follow the paint manufacturer's recommendations for the amount of time required for proper cure and how far the UV lamp should be positioned from the painted surface. Undercoat can be sanded as soon as it is cured.

Block Sanding

Along with featheredging, block sanding will help make a repair invisible. Block sanding the surfacer removes high spots, leveling the entire repair to the same height as the surface surrounding the repair. See **Figure 28-27**. Surfacer fills the low area created by featheredging. Improper block sanding or featheredging will cause bull's eyes in the new paint. Bull's-eye, also called contour mapping, occurs when the outline of the featheredge is visible in the top coat. One method of block sanding surfacer involves using dry, 320-grit sandpaper wrapped around a sanding stick. A sanding stick is hard, flat, and will not flex. It is an ideal tool for block sanding surfacer flat.

Guide coat is used to locate high and low spots, sanding scratches, and other surface imperfections during the block sanding process. Guide coat is a contrasting color of paint or powder applied to a surface prior to block sanding. A light mist-coat of paint is sprayed on the surface or dry guide coat powder can be wiped on the surface with a sponge-like applicator. As the surface is block sanded, the guide coat is gradually sanded off. Slowly move the sanding block back and forth in an X-pattern. Do not press down too hard. Guide coat remains in low areas, giving the technician a clear indication of where additional bodywork is required. See **Figure 28-28**. The goal of block sanding with guide

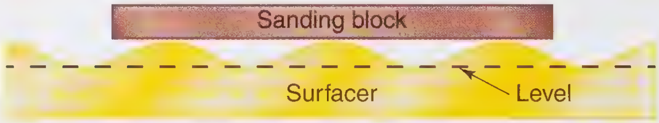


Figure 28-27. *Block sanding levels the surfacer by removing all the high areas, making the entire repair area the same height as the surrounding surface.*

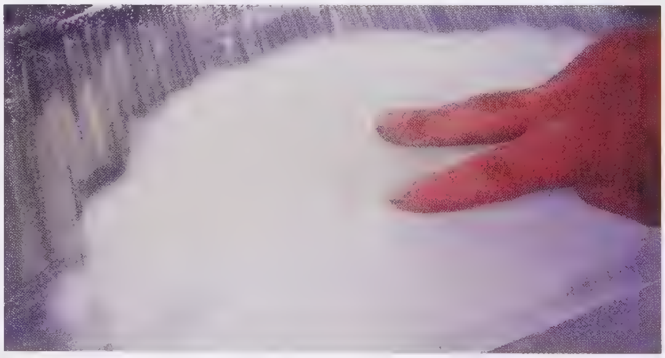


Figure 28-28. *Guide coat remains in low areas giving the technician a clear indication of where additional bodywork is required. Two small low areas are visible.*

coat is to sand until all the guide coat is sanded off. The absence of guide coat, with no exposed bare metal areas (high spots), indicates a level surface.

Always follow the contour of the panel when block sanding by hand. If block sanding exposes high spots—bare metal or bare body filler—before all of the guide coat has been removed, additional bodywork is needed. Also, if scratches cannot be block sanded out, they should be filled with 2-part spot putty and resurfaced after block sanding is complete.

The sanding stick should be cut to the proper length to span the width of the repair area. A high-crown panel should be block sanded by holding the sanding stick on edge while sanding with the crown of the panel. See **Figure 28-29**. Do not sand across the crown or diagonally; sanding with the crown will give consistently good results. On low-crown surfaces, follow any slight crown that is present while holding the sanding stick flat. To properly level the surfacer, there must be consistent pressure on the length of the stick. To accomplish this, position your fingers evenly along the stick. See **Figure 28-30**.

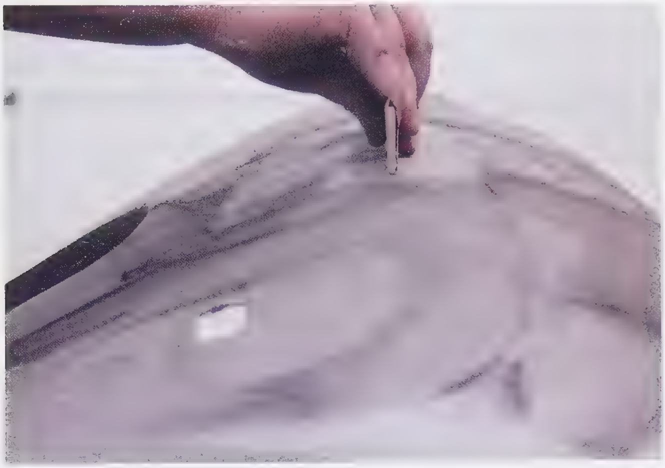


Figure 28-29. *Turning the stick on edge will sand a high-crown area.*

On double-crown panels, the sanding stick cannot bend to adequately level the surfacer. Therefore, a flexible sanding block should be used. See **Figure 28-31**. Bend the block to the proper shape to follow the double-crown contour. The sandpaper will not bend with the flexible block. There will be tearing where the block is stretched and wrinkling where the block is compressed. Block sand up to or down to a bodyline, but never sand across or over a bodyline as this can cut through the paint and expose metal.

Use the edge of the sanding stick to block sand inside a recessed bodyline. The sanding stick can be held on edge to block sand the inside of a concave surface. A teardrop-shaped sanding block can also be used to sand a concave surface. Experienced technicians may have dozens of sanding blocks of every imaginable shape and size. Some of these sanding blocks are custom fabricated. The point is to match the sanding block to the vehicle's surface to obtain optimum results. For example, round foam pipe insulation, when wrapped with sandpaper, makes a perfect block for sanding concave surfaces.

Power block sanding uses 320–400-grit sandpaper on a soft/intermediate pad mounted on a DA sander. Guide coat is applied to the surfacer. The sander is moved perpendicular to the crown in rows from one end of the surfacer to the other. Power block sanding, though faster than hand block sanding, is not as accurate. See **Figure 28-32**. Power block sanding cannot bridge the repair area and level the surfacer as well as hand block sanding.

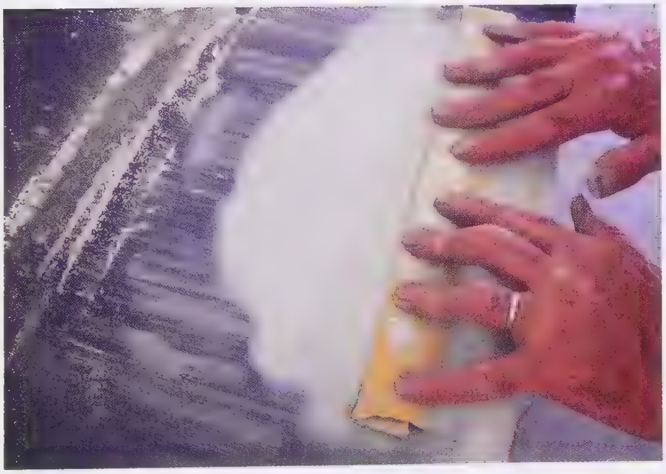


Figure 28-30. *When block sanding surfacer, spread your fingers to evenly distribute the pressure on the stick. This will gradually level the surfacer.*

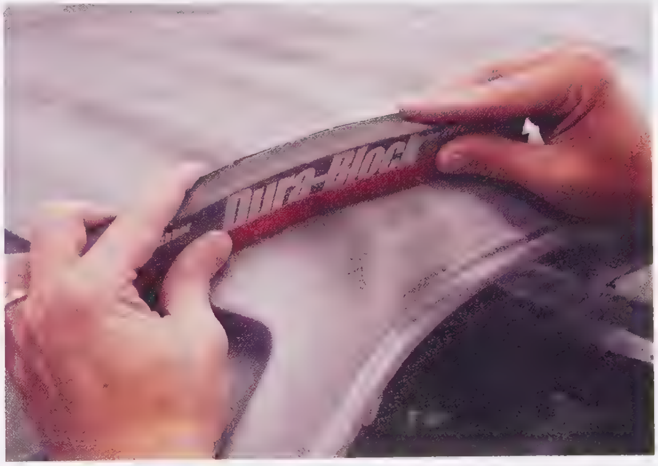


Figure 28-31. *A narrow, flexible block is useful for block sanding a double-crown area.*

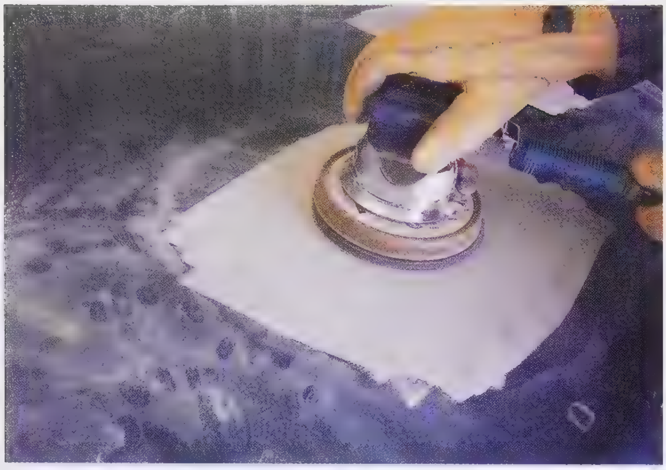


Figure 28-32. *Power block sanding quickly levels surfacer. The underlying surface must be straight, as power block sanding will not level as well as block sanding by hand.*

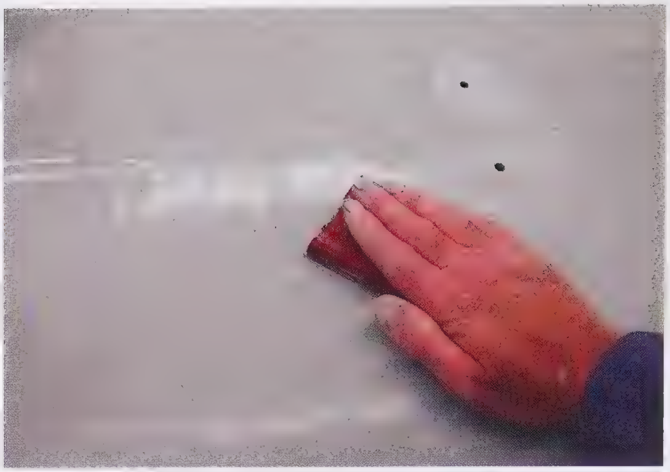


Figure 28-33. *Sanding in circles removes the straight scratches caused by block sanding.*

NOTE

Sanding pads are made of molded foam attached to a fiberglass backing plate. Soft and intermediate sanding pads mounted on a DA are typically used in collision repair. Hard pads are used for sanding and polishing flat surfaces such as granite countertops and have no applications in collision repair. The difference between a soft and intermediate pad is in the degree of flex in the pad itself. Interface pads can be placed between the DA pad and the sanding disc to soften the action. Backup pads to stiffen the pad and reduce flex are available as well. Refer to manufacturer's recommendation and match the sanding pad to the job.

Finish Sand

Hand block sanding with 320-grit sandpaper will create straight scratches in the surfacer. Painting over these scratches will leave visible sanding scratches in the basecoat. Remove the 320-grit scratches by hand with 600-grit wet sandpaper. Use a sanding pad to prevent making finger gouges in the surfacer. Soak the sandpaper in water for a few minutes before wet sanding, as this makes the sandpaper more pliable. Move the pad in a circular motion when wet sanding, as shown in **Figure 28-33**. This will remove the straight scratches caused by block sanding. When sanding in the same direction as the scratches, it is difficult to tell when the scratches are removed because wet sanding sludge temporarily fills the scratches. Sanding in circles ensures that the scratches will be removed. Keep the surface wet while finish sanding. Remove sanding sludge with a squeegee. See **Figure 28-34**. Replace sandpaper when it loses friction and begins to glide over the surface.

Power block sanding with 400-grit sandpaper on a DA *may* produce a surface smooth enough to allow basecoat application without the fear of sanding scratch swelling. This is because the DA sander makes tiny circular scratches that are less obvious than the straight block sanding scratches created with 320-grit sandpaper. Check the paint manufacturer's recommendations for finish sanding requirements. If more sanding is required, use 600- or 800-grit dry sandpaper on a DA.

Sanding clearcoat is not the same as sanding the basecoat. Sanding a clearcoat enhances the finish by removing runs, bits of debris, or other flaws. Make sure that the work area is well lit and remember that you want to remove the flaws, not the clearcoat.

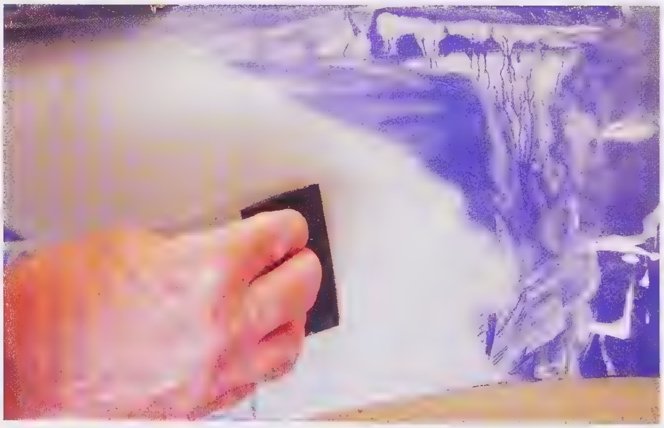


Figure 28-34. *Wet sanding creates sanding sludge. Sanding sludge is easily removed with a squeegee.*

There are four ways to scuff clearcoat on panels that will be blended:

- 800-grit sandpaper on a soft/intermediate pad on a DA.
- 1000-grit sandpaper with a hand sanding pad.
- A wet, gray scuff pad and sanding paste.
- Damp 800-grit sandpaper with a soft/intermediate pad mounted on a DA.

In all these methods, the existing clearcoat is dulled. Any orange peel left in the clearcoat, visible as shiny dots, will show up as orange peel in the new paint. So, be sure to dull the entire surface. Areas that will be melted can be lightly scuffed with 2000-grit wet sandpaper or a wet, gold scuff pad and sanding paste.

NOTE

In a blend, clearcoat is sprayed on the entire panel. In a melt, the clearcoat is only sprayed on part of the panel.

Blow off Vehicle

A quality paint job always begins with a clean vehicle! Use an air gun to blow dust off the entire vehicle *before* it is moved into the spray booth. Be sure to blow out every panel opening, even areas that will not be painted. During spraying, hidden dirt can be dislodged by compressed air and land in the paint. If wet sanding sludge is present, it is easier to wipe it off while wet than it is to allow it to dry and then blow it off.

WORKING GREEN

Use a vacuum sander to collect dust during sanding operations.

Clean with Pre-Paint Solvent

After the vehicle is blown off, the areas that will be refinished must be cleaned with pre-paint solvent. ***Pre-paint solvent*** is not as aggressive as pre-sand solvent. It evaporates quickly and does not have time to soak into the surfacer and cause sand scratch swelling. Pre-paint solvent will remove fingerprints and minor oil-based contamination.

Mask for Topcoat

Masking for the topcoat is usually done inside the spray booth. Make sure the vehicle is clean before masking. Tape will not stick to dirt, and you never want to bring dirt into the spray booth. The level of surface prep will determine what will be masked. Start on the inside of the vehicle. When masking along edges, scuff the surface that will be masked. Scuffing is the only way to ensure the paint will adhere properly. If this is not done, the paint will not stick to the area directly adjacent to the tape. The paint could peel off when the masking is removed. **Figure 28-35** shows how refinish paint can peel when removing masking. In this example, tape was applied to make the edge of the spray area. The surface was scuffed right up to the edge of the tape. When paint was applied, it bridged over the tape. Removing the tape after painting caused the paint to peel off with the tape. Sanding up to the tape will not allow good paint adhesion adjacent to the tape. By scuffing the area first and then taping *over* the scuffed edge, the paint can adhere and not peel off when the masking tape is removed.

If panels will be painted on the vehicle, the vehicle should be masked in the following order:

1. Panel openings.
2. Window moldings.
3. Windows.
4. Moldings and stripes.
5. Wheels and wheel openings.
6. Edges.
7. Adjacent panels.

A spray gun will discharge enough air to move insecurely attached paper or tape. The moving, flapping paper can detach and be blown into wet paint. All masking paper must be attached securely, but it also must be applied in such a way as to promote easy removal.

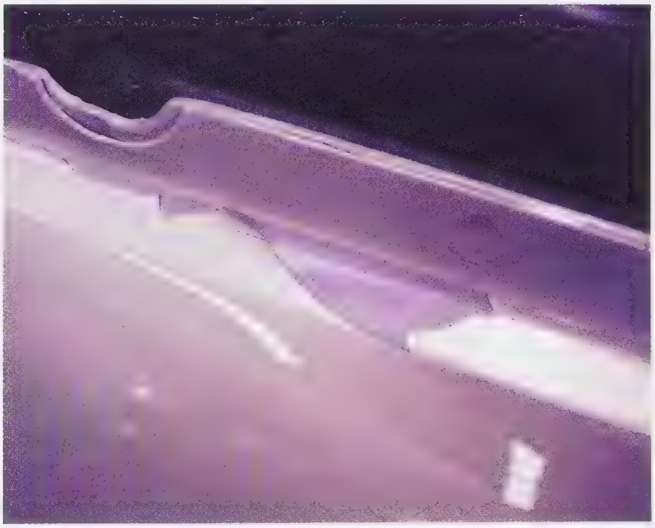


Figure 28-35. *The basecoat and clearcoat bridged the masking tape. When the masking tape was removed, the paint came off with the tape. Paint adhered better to the tape than the vehicle.*

Panel Openings

Panel openings have two sides: an open side and a blind side. The open side will be exposed to overspray as the panel is painted. The blind side will not be directly exposed to overspray, but pressurized air can easily propel overspray through a narrow panel gap and contaminate the blind side.

When using masking tape and paper, the open side will need to be back taped to prevent making an edge. The blind side needs to be protected with paper and tape but does not necessarily need to be back taped. **Figure 28-36**. To mask a door opening, back tape the quarter panel and rocker panel with 3/4" masking tape. Attach masking tape and 6" masking paper to the back tape. Apply 2" masking tape along the front edge of the door. About 1/2" of the tape should be on the door edge, and the rest of the tape should fill the gap between the door and fender when the door is closed. It may be difficult working around the hinges. The blind edge of the rear surface of the door should be covered with masking tape and 6" masking paper. If the door handle, lock cylinder, and mirror have been removed, slide masking paper inside the door to cover these openings. Foam tape fills panel gaps in the same way as back tape and paper. **Figure 28-37** shows how foam tape and masking tape are used to mask a door.

If foam tape is used instead of masking tape and paper, the foam tape should be placed on the corner of the panel. The foam will fill the panel gap; no back taping or blind side masking is required. See **Figure 28-38**.

To mask a hood opening, back tape 3/4" masking tape to the fender edge. Then, attach masking tape and 6" masking paper to the back tape. This covers the open side of the fender. If the hood has a flange, it also will form an open side. Back tape the flange with 3/4" masking tape and cover any exposed paint with masking tape. If the hood does not have a flange, the blind side usually does not need to be masked because the hood will shut on the masking paper on the fender. A deck lid opening is masked in the same way as the hood. The gas cap door can be masked by back taping around the opening. The blind side of the gas cap door normally does not need to be protected.

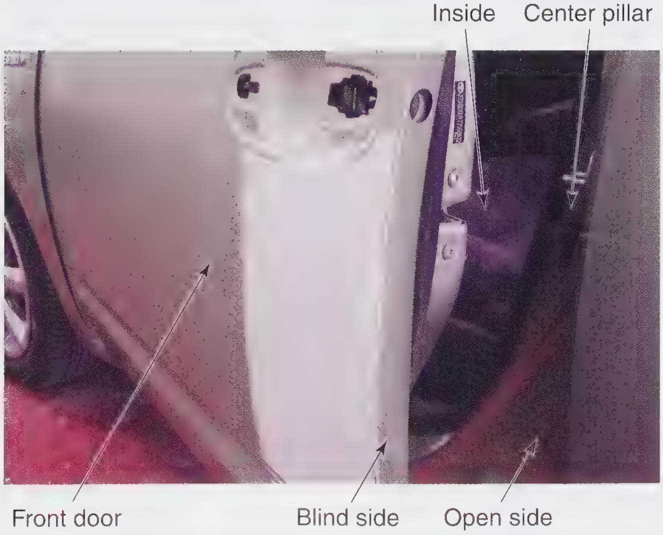


Figure 28-36. *The blind side and the open side will be covered with overspray if they are not protected with masking.*

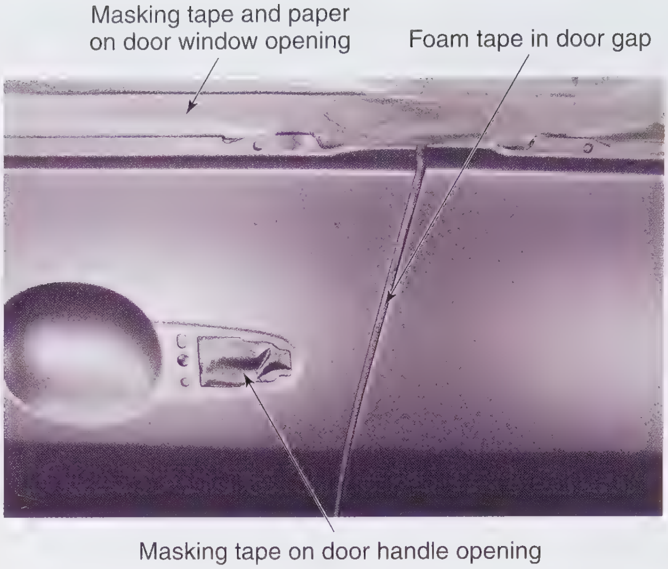

Masking tape and paper on door window opening
Foam tape in door gap
Masking tape on door handle opening

Figure 28-37. *These doors have been masked from the inside with foam tape (door gap), masking tape (door handle opening), and masking paper and tape (window opening). At this point, only the basecoat has been sprayed. Notice the overspray on the masking.*

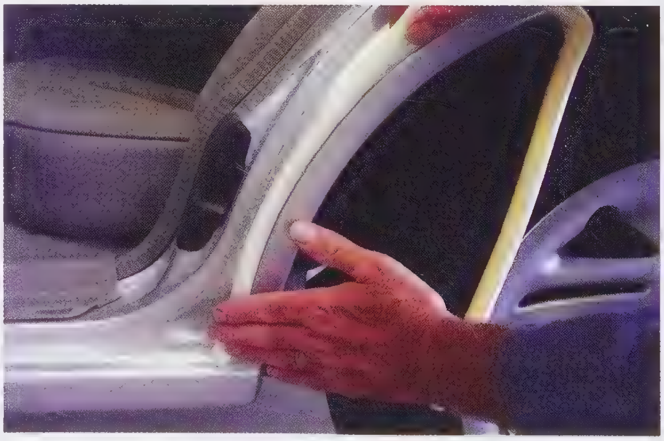


Figure 28-38. *Foam tape, applied to the edge of one panel, fills the gap between panels.*

Window Moldings

After masking the inside of the vehicle, close the doors, hood, and deck lid and mask window moldings as required. Masking on the molding will leave a paint edge. Because it is difficult to sand the area immediately adjacent to the molding, this paint edge may peel. To prevent this problem, raise the molding by inserting rope or rigid tape under it. Sometimes the molding will adhere to the paint. If necessary, release the molding with a plastic bone. Insert the bone between the window molding and the paint, and move the bone all the way around the molding. Next, clean dust and wax residue from under the molding by soaking a paper towel with pre-paint solvent and running it under the molding. Follow with a clean paper towel. After cleaning, scuff the area under the molding with a gray scuff pad. Blow out the area under the molding and clean it again with solvent.

After cleaning and scuffing, carefully push the rope into place under the molding. See **Figure 28-39**. Apply masking tape over the raised molding. When using rigid tape to raise molding, first select the proper width of tape. Wide tape is used to raise a wide molding. Raise the corners first. Cut a wide piece of rigid tape into 1" sections. Insert the rigid portion of the tape under the corner and pull back on the adhesive portion, attaching it to the window. **Figure 28-40** shows a raised corner.

Cut rigid tape to the proper length to raise the straight portions of the window molding. Insert the rigid portion of the tape under the molding and stretch the adhesive portion back to the window, raising the molding. See **Figure 28-41**. Apply masking tape and paper to the rigid tape.

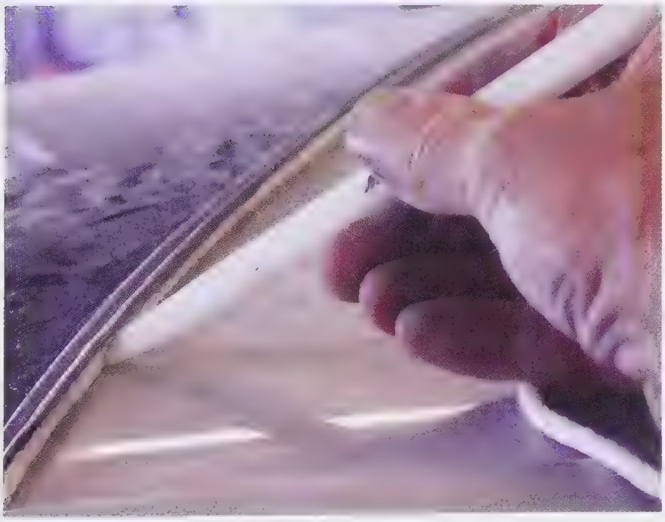


Figure 28-39. *This windshield molding has been raised with a length of rope.*

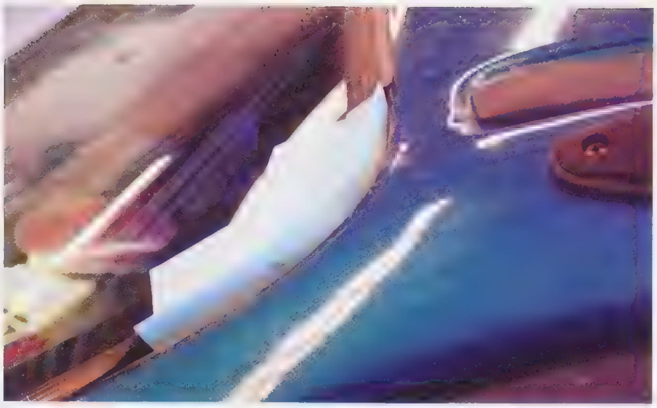


Figure 28-40. *The corner of this windshield molding has been raised with rigid tape. Notice the obstructions that remain on the panel.*

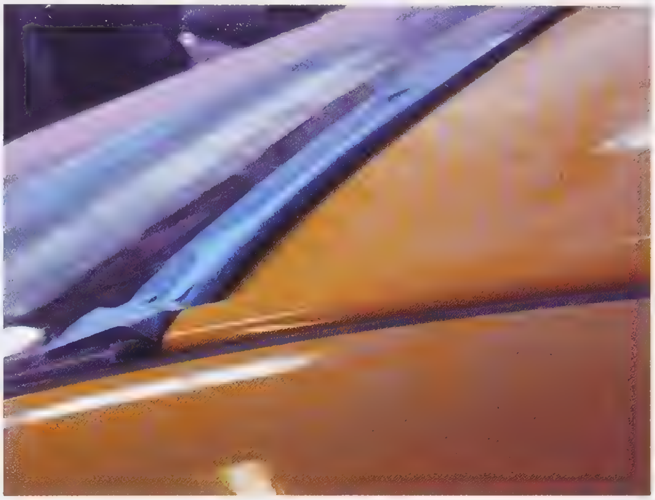


Figure 28-41. *The straight portion of a windshield molding has been raised with rigid tape.*

NOTE

Depending on the level of surface preparation, some shops will simply mask the window molding rather than raise it.

Windows

Masking paper must be folded to fit when masking curved back glass and windshields. Folds can trap dirt and dry overspray. These contaminants will be blown out of the folds during spraying and land in the wet paint. All masking paper folds should always be taped over to prevent this from occurring.

When masking the windshield on a vehicle that does not have a cowl vent panel, tear off a piece of 18" masking paper the length of the lower portion of the windshield. Slide most of the masking paper under the hood and attach the top to the lower windshield molding. Next, tear off a length of 18" masking paper the length of the upper portion of the windshield. Attach this paper to the masked molding. Fold the paper at the sides of the windshield to fit the windshield and then tape it in place. Attach 18" masking paper as needed to cover the rest of the windshield. **Figure 28-42** shows a masked windshield.

If the windshield or back glass has been removed from the vehicle, a piece of cardboard can be cut out to fill the opening. However, the cardboard may contaminate wet paint with fibers, so masking paper should be applied over the cardboard. To mask an opening with paper, construct a grid of 3/4" masking tape. Span the length of the windshield opening with masking tape placed every 6". Next, place masking tape every 6" across the width of the window. Make sure the pieces of tape adhere to each other where they overlap. The tape forms a grid that will support the masking paper. See **Figure 28-43**. Apply the masking paper to the tape grid.

Mask door windows and side windows next. If the door run channel and window glass have been removed, open the door and mask from the inside. Clean out the window frame and attach masking tape and paper to the inside of the outer portion of the frame. Make a grid of 3/4" tape to support the paper.

If the door run channel has not been removed, work from the outside of the vehicle. Tape the run channel and cover the door glass with masking paper. Quarter glass can be masked by attaching 18" masking paper to the molding at the top of the window and folding the paper as needed. Check all masking to make sure there are no gaps in the paper, and remember to tape over all folds.

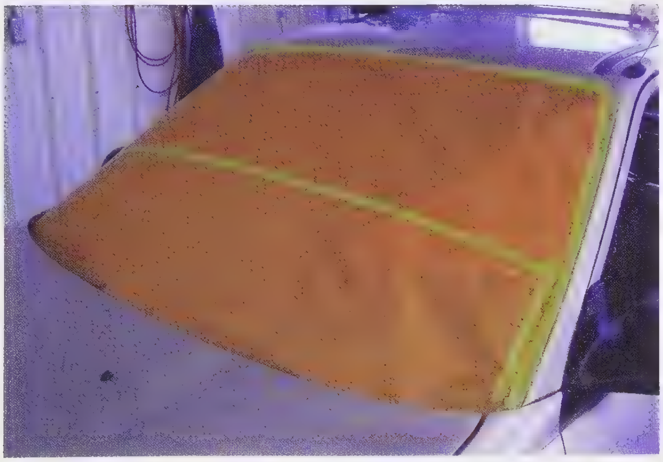


Figure 28-42. *Masking tape is applied to the windshield molding. Masking paper and tape cover the windshield.*

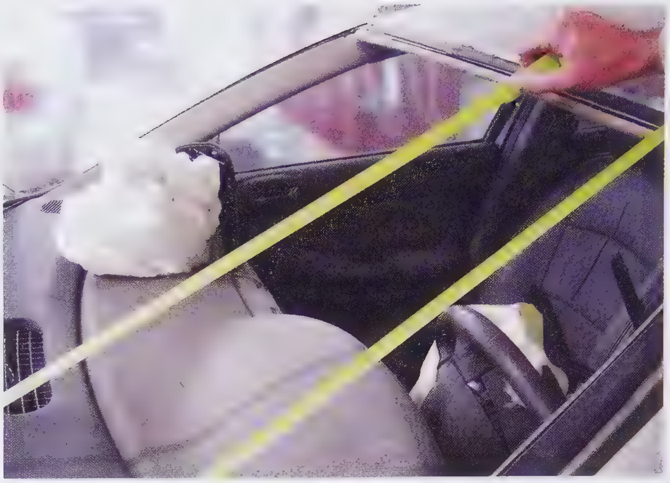


Figure 28-43. *A grid of masking tape is applied to support masking paper in the windshield opening.*

Moldings and Stripes

If moldings are left on the vehicle, mask them next. Clean and scuff the paint as close as possible to the edge of the molding. See **Figure 28-44**. Use 1/8" fine-line masking tape on the edge of the molding. The sharp border formed by this tape is less likely to cause the paint to peel from the panel when the masking is removed. One way to do this is to mask the obstruction with 1/4" masking tape, leaving 1/8" of the molding exposed at the edge. Cover the exposed portion of the molding with the 3/4" fine-line tape. Make sure the tape does not overlap the paint. Remove the fine-line tape after the clearcoat is sprayed but before baking or curing. Removing the tape while the clearcoat is still wet will prevent any peeling problems. Stripes can also be masked with fine-line tape.

Wheels and Wheel Openings

Wheels can be protected with a wheel masker. However, these canvas covers will accumulate overspray and may become a source of contamination. To avoid this problem, the wheels can be masked with 18" masking paper. Attach one piece along the bottom portion of the wheel so it wraps around each end of the tire. The masking tape along the edge of the paper should adhere to the wheel and tire. The bottom end of the masking paper should touch the floor. Use another length of masking paper to wrap around the upper portion of the wheel. Attach the masking tape on the second length of masking paper to the masking tape

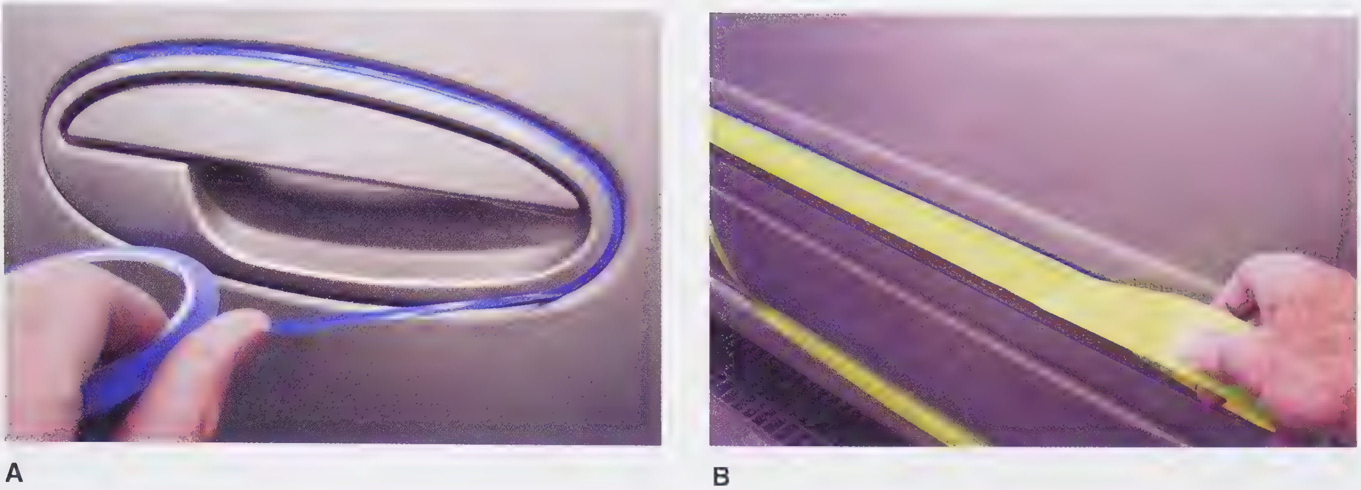


Figure 28-44. *A—The narrow molding in the door handle is masked with 1/8" fine-line masking tape. B—The door molding edge is masked with 1/4" tape, then the inner portion is covered with masking tape.*

on the first length. This will protect the wheel and tire. See **Figure 28-45**. Use additional masking tape to affix the upper masking paper section to the wheel house. Single-use plastic wheel covers are available. These fit over the tire and are held in place with masking tape. The plastic covers are thrown away after the vehicle is refinished.

Always mask wheel openings to keep overspray off suspension parts and prevent dirt from contaminating the paint. Aluminum foil is an effective tool for masking suspension components. The wheel opening can be coated with liquid mask or covered with masking paper and tape. Liquid mask can be applied with a spray gun or special applicator. It will dry to a clear film, which can be rinsed off with water after the vehicle has been painted. Liquid mask should not be applied next to the spray area because pressure from the spray gun can blow it off. Instead, create a buffer zone of 18" masking paper.

To mask a wheel opening, first clean the fender liner. Even after washing the vehicle, fender liners may still be contaminated with dirt and road tar. Use a pre-sand solvent to remove tar. Some plastic fender liners are not easily masked because masking tape will not stick to them. If this happens, try wiping the plastic with lacquer thinner. Apply 18" masking paper and tape to cover the entire fender liner.

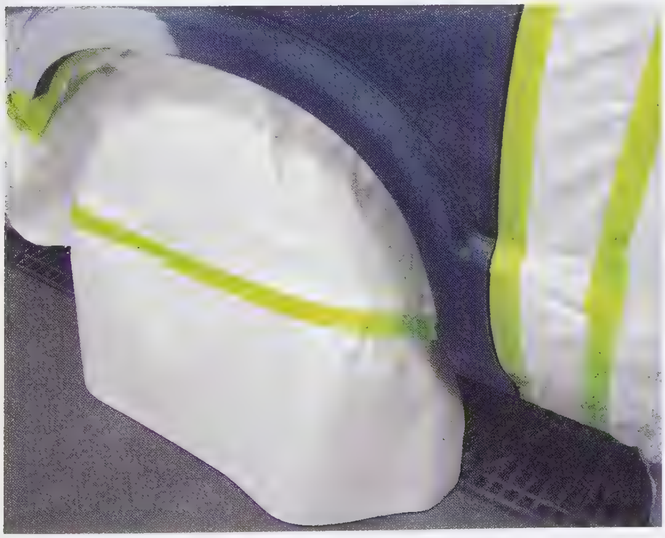


Figure 28-45. *The wheel opening is masked with paper and tape.*

Edges

Sharp body lines and panel gaps can serve as edges. Back taping is the recommended method of masking along these edges. Some vehicles have a sharp body line in the roof panel above the doors as shown in **Figure 28-46**. A body line can serve as an edge if it runs the length of the panel. Back tape the body line.

Filled panel gaps, such as the seam between the quarter panel and rear body panel, can also serve as an edge. Pickup trucks have a seam in the back of the cab that can be used as an edge. See **Figure 28-47**. Reaching this seam is difficult on some trucks, as there is not enough room to fit hands between the cab and the bed. With both body lines and filled seams, lightly scuff the area where the masking tape will be applied. This will help ensure that the paint adheres to the surface adjacent to the tape. Some seams are not filled, such as the seam at the front of a pickup truck bed. These seams can also serve as an edge.

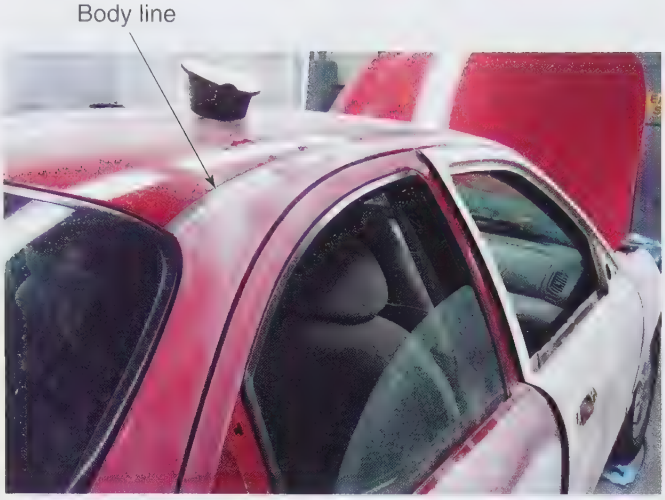


Figure 28-46. *This uniside vehicle has a seam in the roof. The seam makes an excellent edge when painting the side of the vehicle.*

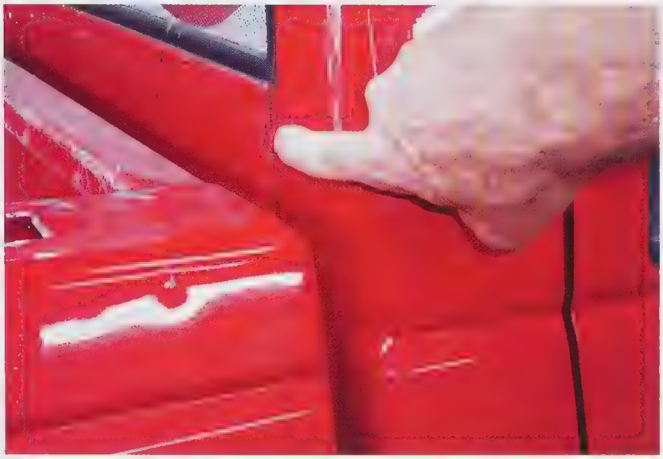


Figure 28-47. *This seam in the back of the pickup truck cab serves as an edge when painting the cab corner.*

Adjacent Panels

Mask panels adjacent to the spray area with 18" masking paper. Straight panels are easy to mask, but most panels on a vehicle are not straight. Most panels are crowned or have body lines. Try to tear off enough masking paper to cover the panel with one piece. It will take a while to develop the skill to judge panel length. Always tape over any folds in the masking paper.

Any part that will not be masked with tape or paper should be covered with ***masking plastic***. Tuck the plastic under the masking paper and tape it down. Masking plastic must be properly oriented to be effective. The brand name printed on the plastic should be legible. If the brand name is backward and not legible, the plastic is upside down. Overspray will not adhere to masking plastic if it is upside down. Air pressure from the spray gun will then blow the overspray off the plastic and into the wet paint. **Figures 28-48** offers multiple examples of effective masking strategies.

Blow off Vehicle

After masking, use a blowgun to remove contaminants from the vehicle. Begin by turning on the spray booth exhaust fan and blowing off the floor of the spray booth. Blow the contaminants on the floor toward the spray booth exhaust filters. Next, blow off the panels that will be sprayed, the masking paper, and all panel openings.

Tack

After blowing off loose debris, a ***tack rag*** should be used to further clean the surface. Unfold the tack rag and make a loose pad as shown in **Figure 28-49**. Gently, glide the rag over all surfaces that will be painted. Apply light pressure. Do not push the tack rag into the surface, as this may leave a sticky residue. You will be amazed by the amount of super-fine contaminant that the tack rag will collect.

Seam Sealer

Panel joints must be sealed to prevent the accumulation of contaminants and to keep out water. ***Seam sealer*** is used to fill the gap between panels. Gaps will be present when welded panels are installed, such as a roof, quarter panel, trunk floor, rear body panel, radiator support, or lower unibody frame rail. Bonded panels, such as door skins, may also require seam sealer.

The force of a collision can easily open gaps between panels. If a quarter panel is damaged in a collision, seams in the trunk floor may be torn open. An open seam will allow water and exhaust gas to enter through the trunk. Brushable seam sealer is applied to surfaces such as the trunk floor. The brush will leave a rough surface that duplicates the factory appearance. Seam sealer can be applied smooth to outside surfaces of panels.

One-part seam sealer dries through evaporation of the solvents. Two-part seam sealer begins to cure after it is mixed with a hardener. The two-part sealer is self-leveling and will make a smoother application. When applying a one- or two-part seam sealer from a tube, follow all of the manufacturer's instructions.

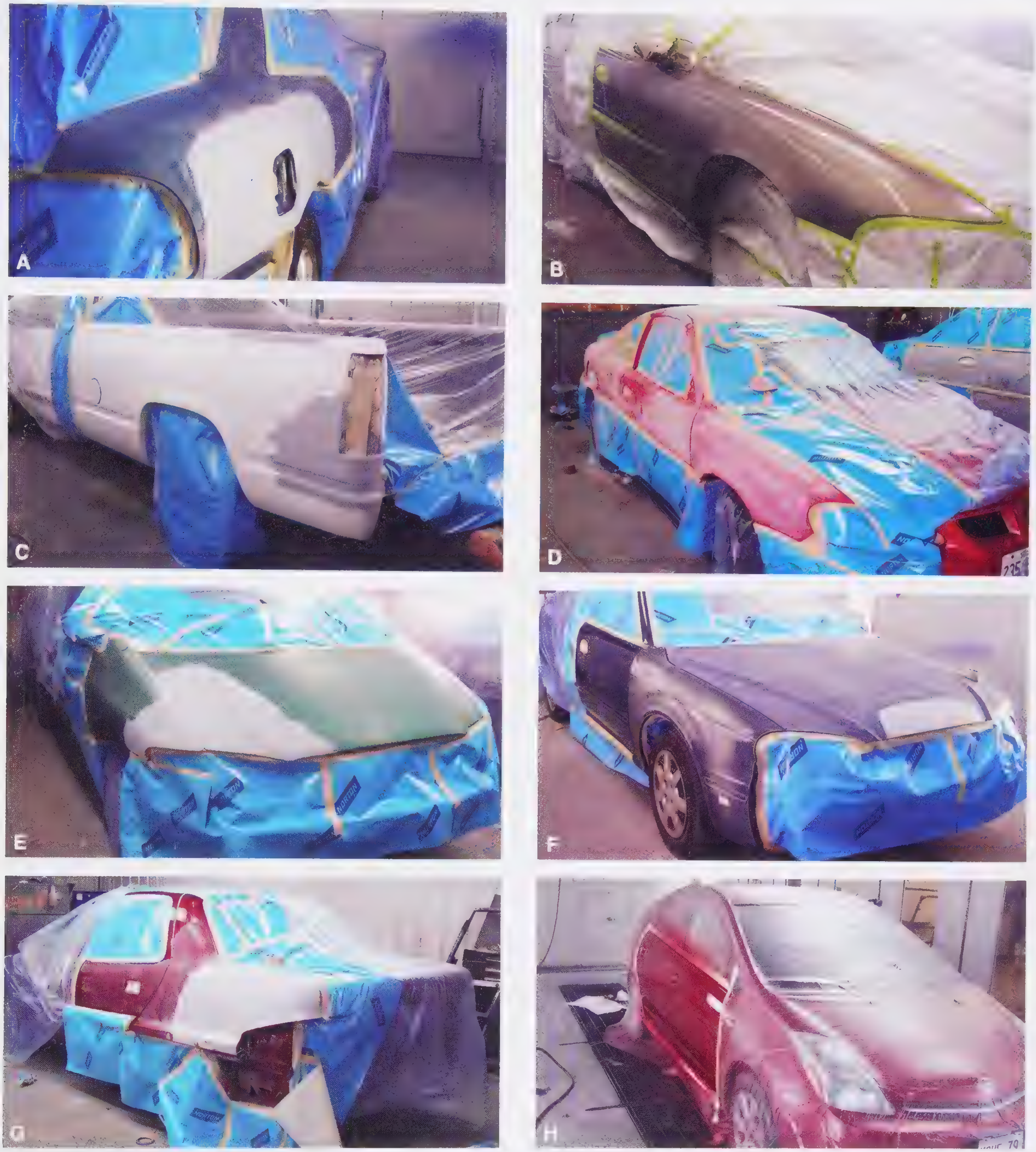


Figure 28-48. *A—This repair calls for a melt in the sail panel, so masking extends well beyond the repair area. B—The molding on the door remains on the vehicle. The area around the molding was cleaned and scuffed prior to masking. C—Notice how the inside of the wheel well was masked off for this repaint of a bed side. D—The door molding is masked and used as an edge. Note also how obstructions (door handles and window trim) have been removed. E—Hood and fender have been masked off to the nearest edge. Note how creases in the masking paper have been taped to avoid trapping contaminants. F—Effective masking protects the rest of the vehicle from overspray. Only the repair area remains exposed. G—Masking paper, tape, and plastic roll material are used to create a hiding edge and protect the vehicle from overspray. H—This vehicle was first covered with plastic sheeting. The area to be painted was cut out and masking tape was used to make an edge around the area to be sprayed.*

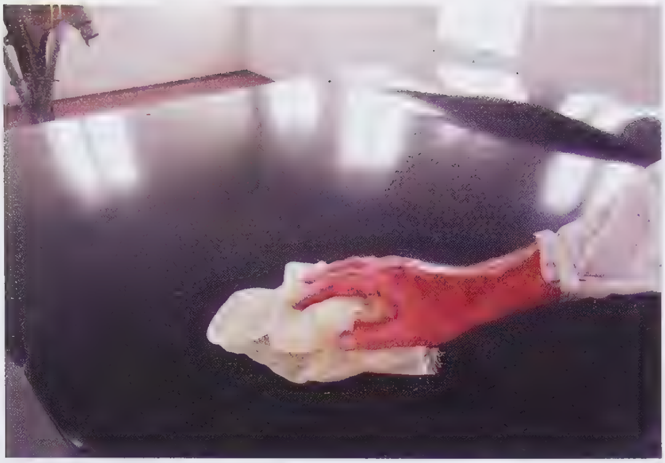


Figure 28-49. *Unfold the tack rag completely and lightly rub the surface to be painted.*

NOTE

Apply the seam sealer just before sealer or topcoat.

Apply 3/4" masking tape to each side of the seam gap. This will keep the sealer where it belongs. Use a mixing tube to apply the seam sealer. Do not use the first 6" of sealer that flows out of the tube to ensure that the applied product will be well mixed. Carefully apply the seam sealer to the gap, pulling the mixing tube along the seam as shown in **Figure 28-50**. A power caulking gun creates a smoother bead than a manual caulking gun because it produces a more uniform flow of material. After the seam sealer is applied, it can be smoothed and leveled with a gloved finger. Remove the masking tape immediately after applying. Allow seam sealer to cure before applying sealer or basecoat.

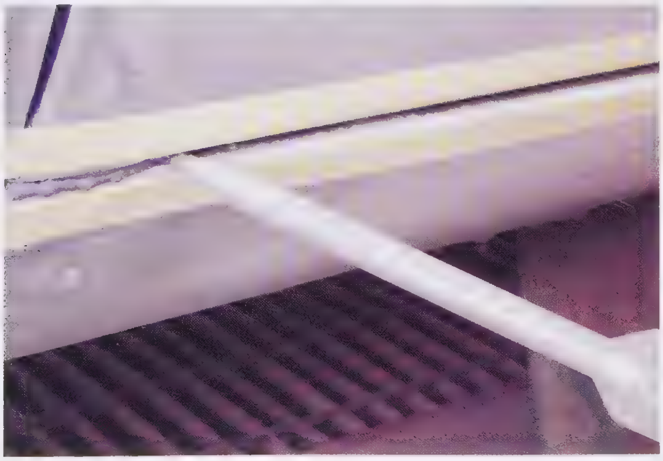


Figure 28-50. *The gap between the quarter panel and the rocker panel has been taped to confine the seam sealer. The seam sealer is applied with a caulk gun while moving along the gap.*

Rocker Panel Spray

Rocker panel spray forms a thick, clear, protective layer on the lower surfaces of vehicles. It is available in an aerosol can. Clean off the panel in the same way as you would when preparing for seam sealer application. Mask off the area to be sprayed with fine-line masking tape and 18" masking paper. The texture must be matched to any original rocker panel spray remaining on the vehicle. Holding the aerosol can farther from the vehicle results in a coarser, drier appearance. Holding the can closer makes for a wetter, smoother look. Before spraying the vehicle, practice to find the correct distance to match the original texture. See **Figure 28-51**. Spray the required number of coats. Allow the rocker panel spray to cure before applying basecoat.

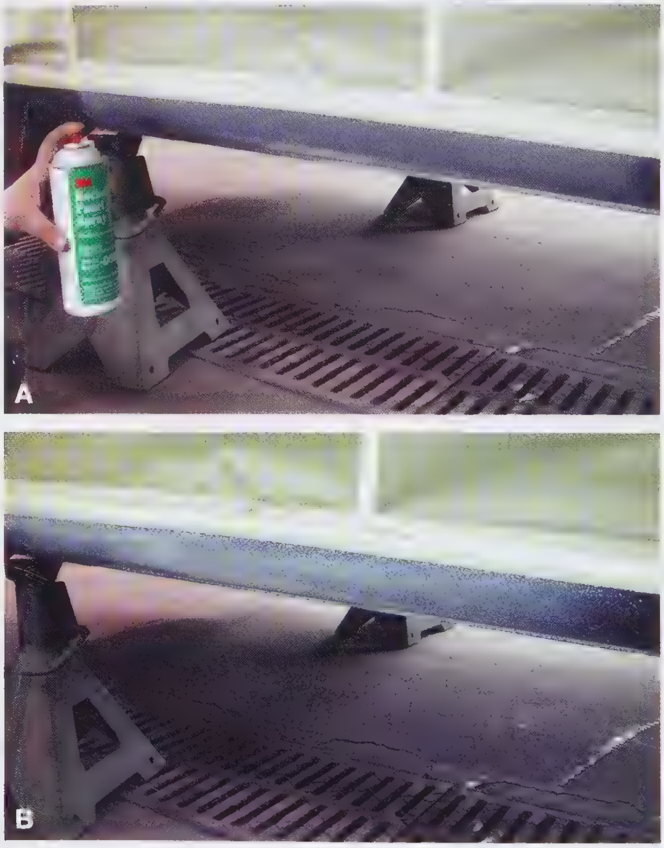


Figure 28-51. *A—Rocker panel spray can be dispensed from an aerosol can. B—Apply enough coats of rocker panel spray to match the texture of the existing rocker panel.*

Aluminum Preparation

Aluminum preparation is similar to steel preparation in that many of the solvents and undercoats are the same. However, there are some differences. For example, there is a special etching acid and conversion coat for aluminum.

Aluminum will begin to oxidize when exposed to air. This nearly invisible layer of corrosion will prevent the undercoat from adhering. Use the aluminum acid etch and conversion coat in the same way as you would use comparable products made for steel surface preparation. Many manufacturers recommend that epoxy primer be applied to treated, bare aluminum before the application of body filler. Self-etching primer can be sprayed on bare aluminum. Once the bare aluminum is coated with primer, the preparation procedure for an aluminum panel is the same as for a steel panel.

CAUTION

Use a dedicated set of tools when working on aluminum to avoid the possibility of contaminating aluminum with steel shavings or particles.

Surface Preparation for Specific Types of Damage

This section explains how to prepare various types of damaged surfaces for painting. Each procedure is broken down into steps. These steps follow the same pattern: evaluate the surface, plan the repair, remove obstructions, remove contaminants, featheredge, mask for primer, apply undercoats, cure, block sand, mask for paint, and clean.

Scratch

Begin by evaluating the surface. Look for peeling, cracking, or evidence of repaint. Determine how much paint is on the panel. Then decide how much of the panel will be painted and if adjacent panels will be blended.

For the best durability, remove all obstructions in the area to be painted. Masking obstructions will leave edges in the new paint. These edges may cause peeling. Wash the panel with soap and hot water to remove contaminants. Remove wax, grease, and tar with pre-sanding solvent.

Featheredging is required for an invisible repair. Simply filling the scratch with surfacer will leave a visible line in the clearcoat. Featheredge the scratch to a gradual taper with 80-, 180-, and 320-grit sand-papers. The featheredged area seen in **Figure 28-52** was once a scratch too deep to be buffed out. It will require repair and repainting. After featheredging, clean the surface and blow off any remaining dust.

Mask the panel for undercoats, and spray a self-etching or epoxy primer over the bare metal. Follow the paint manufacturer's recommendations as to the number of coats and flash time. After priming, apply surfacer. The surfacer will fill the slight depression in the surface created by featheredging. Spray three coats. Stay just inside the 320-grit scratches. Allow the primer and surfacer to cure according to the manufacturer's instructions.

After the primer and surfacer have cured, apply a guide coat and block sand until the guide coat is gone. If the guide coat indicates that no additional bodywork is necessary, then wet sand with 600-grit to remove the 320-grit scratches. Finally, dry the panel and blow off any dust, clean the surface to be painted with pre-paint solvent, and mask the panel for paint.

Body Filler

Begin preparation by evaluating the surface. Look for pinholes in the body filler. Pinholes can be filled with spot putty. After planning the repair, remove obstructions, eliminate contaminants, and featheredge the filler. Clean off the repair area, mask for the undercoat, and apply primer and surfacer. After allowing the primer and surfacer to cure, block sand the repair, making sure that all scratches or pinholes are filled, see **Figure 28-53**. Finally, clean the panel and mask for the topcoat.

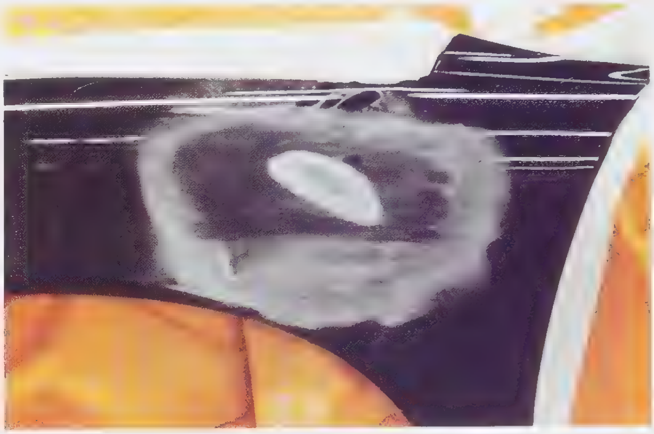


Figure 28-52. *A scratch, too deep to be buffed out, was sanded and featheredged.*

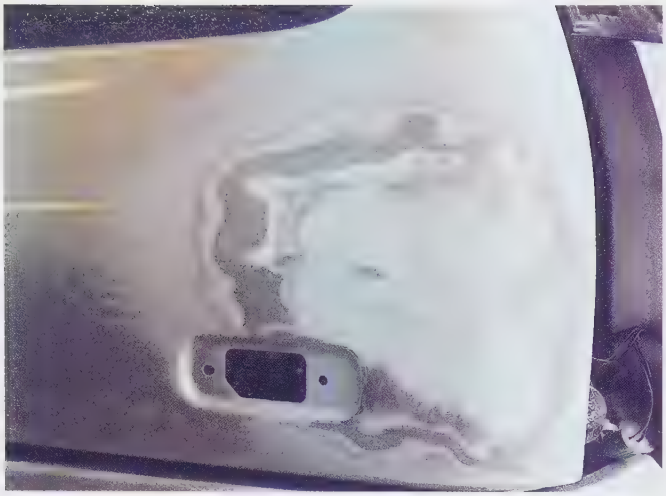


Figure 28-53. *This body filler is ready for paint prep. Notice the scratches in the existing paint and bare metal from block sanding the body filler.*

NOTE

In some shops, vehicles are delivered already primed, surfaced, and blocked.

Bare Metal

When a panel has been stripped, the bare metal should be primed *as soon as possible*. Do not leave metal bare for more than one day. A panel that has been stripped will already have obstructions removed, so surface preparation is shorter.

Begin by examining the surface. If the panel was stripped with a 24- or 36-grit grinding disk, sand the surface with 80-grit and then again with 180-grit sandpaper. This will reduce the depth of the sanding scratches, lessening the chance of ***shrinkage***. Deep sanding scratches can trap solvent increasing the likelihood of surfacer swelling followed by shrinkage as the solvent slowly evaporates during curing. Shrinkage causes scratches to appear in the clearcoat weeks or even months later.

If the panel was stripped chemically, sand the bare metal with 320-grit sandpaper to produce a surface that is ready to mechanically bond with primer. Blow off any sanding dust, clean the panel, and mask it for the undercoats. Apply primer and surfacer. Only one coat of surfacer is needed if the panel was chemically stripped. After allowing the primer and surfacer to cure, block sand the panel. Be sure to remove all scratches. Finally, blow off any sanding dust, clean the panel with pre-paint solvent, and mask the panel for topcoat.

Weld

Welding will burn paint off both the inner and outer surfaces of a panel. To prevent corrosion, both inner and outer surfaces must be prepped. An outer surface of a weld is shown in **Figure 28-54**. This is an ***appearance weld***, meaning the welded area is visible. A ***nonappearance weld*** is on the inside of a panel; it is hidden from view. An appearance weld must be ground down to match the contour of the surrounding panels. A nonappearance weld does not need to be ground away.

Appearance Weld

To prepare an appearance weld, begin by evaluating the surface and planning the repair. After removing obstructions and cleaning the panel, dress the welds. Use a cutoff wheel to grind away most of the weld bead. Use a grinder on any remaining high spots. Grind on the weld but not on the surrounding metal. Do not overheat the area by grinding too long on the same spot.

After dressing the welds, fill slight voids in the repair with two-part spot putty and featheredge. Blow off any sanding dust and clean the panel. Then mask the repair area for undercoat and apply the primer and surfacer. After the primer and surfacer have cured, block sand the repair, blow off the sanding dust, clean the panel with pre-paint solvent, and mask for the topcoat.

Nonappearance Weld

To prepare a nonappearance weld, begin by evaluating the surface and planning the repair. Remove obstructions as necessary and clean the repair area to remove contaminants.

On accessible welds, use a plastic wheel to remove blistered paint and weld scale. On an inaccessible weld, use a long-handled wire brush to remove scale. If this is not possible, use a blow gun to direct a stream of

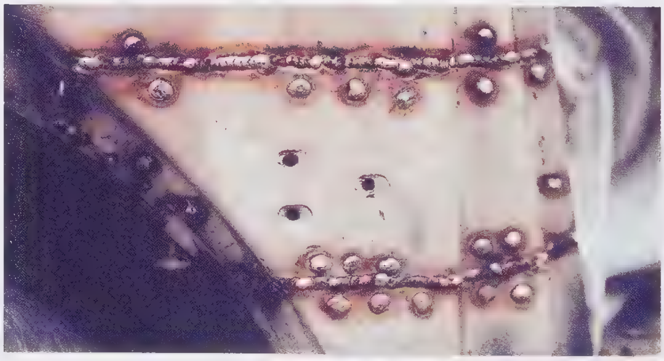


Figure 28-54. *This is a weld on an A pillar. It will be visible when the door is opened.*

compressed air at the weld to blow off scale and blistered paint. Treat accessible bare metal areas with acid etch and conversion coat.

Mask the repair area for primer, apply seam sealer if needed, and apply primer. On inaccessible welds, use a wand to spray epoxy primer on the weld area. After allowing the primer to cure, apply wax-based rust proofing. The combination of epoxy primer and wax-based rust proofing will seal the bare metal to prevent rust.

Rust

External rust begins when the paint surface has been damaged, exposing bare metal. Exposed metal will immediately start to rust. This rust will begin creeping under the surrounding paint. **Figure 28-55** shows what external rust, also called surface rust, looks like. Internal rust, on the other hand, begins on the inside of a panel and works its way out.

Rust often shows up as a bubble in the paint. To determine whether rust is external or internal, probe the bubble with a screwdriver. If the metal under the bubble collapses, the rust is internal, **Figure 28-56**. To fix panels with internal rust, you must cut out all weakened metal and weld or bond in replacement metal. Metal exhibiting external rust can be salvaged. This section will discuss the repair of external rust.

Begin surface preparation in the same manner as you have done with other repairs—evaluate the surface, plan the repair, remove obstructions, and remove contaminants. Use a 24-grit disc to remove paint and grind away rust. After grinding, the rust will look like black specks or spots in the metal. These spots must be removed. If the spots are not completely removed, rust will return. Use a spot sandblaster to remove the black spots. Featheredge the repair area after sandblasting.

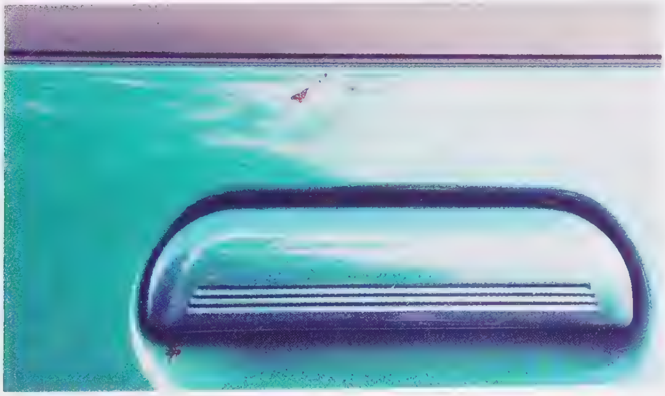


Figure 28-55. *External rust can be removed by grinding and media blasting.*

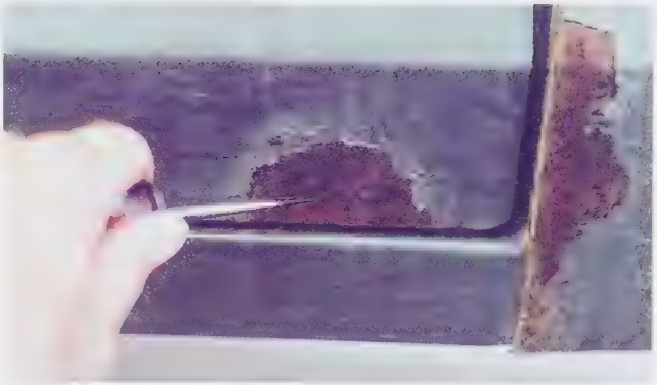


Figure 28-56. *Probing rust with a screwdriver will show if the metal has internal rust. If the metal collapses or if you can poke a hole, the panel has internal rust.*

Spray with self-etching primer or treat the area with acid wash and conversion coating and keep the metal wet for five minutes. Use an abrasive pad to work the acid into the metal. After drying, apply an epoxy primer. Then apply surfacer and allow it to cure.

Sandblasting may leave pits in the metal. Inspect the repair area for pits, and if necessary, fill with spot putty and apply more surfacer. After the surfacer cures, block sand the repair. Blow off any remaining sanding dust, clean the panel with pre-paint solvent, and mask the panel for the topcoat.

Repaint

Preparation is straightforward when repainting over an OEM finish. Begin by evaluating the surface. The paint should not be cracked or peeling. After planning the repair, remove obstructions and clean the surface to remove contaminants. Next, sand the surface with 320-grit sandpaper on a dual-action sander. Do not sand through the OEM clearcoat. The OEM clearcoat acts as a sealer. After sanding, blow off any remaining dust and clean the panel. Mask the panel for paint and apply sealer. The sealer will make the surface a uniform color, allow the topcoat to bond, and prevent the original paint from absorbing the new paint.

Blend

In a ***blend,*** the refinish basecoat is stepped out, coat-by-coat, into the existing basecoat. Blending tapers the coats of paint, making a gradual transition from refinish paint to existing paint. The entire panel is then clearcoated. A blend will hide a slight mismatch in color.

If a panel is replaced, the adjacent panels will be blended. If a panel is repaired, the blend may be confined to that panel if the repair area is small. A large repair or a repair on one edge of a panel will require that adjacent panels be blended. See **Figure 28-57**.

Begin by evaluating the surface and planning the repair. If necessary, remove any obstructions and then clean the panel to remove contaminants. Scuff or sand the panel using one of the following four methods:

- Use 1000-grit sandpaper, water, and a sanding pad to remove any trace of orange peel from the surface of the clearcoat.
- Use 800-grit dry sandpaper on a dual-action sander equipped with a soft pad. The soft pad allows the dual-action sander to float over ridges and bodylines without digging in.
- Use a gray scuff pad, sanding paste, and water. The sanding paste will clean and abrade the surface along with the scuff pad.
- Use a damp, 800-grit disc on a dual-action sander.

Regardless of the method you choose, the surface should be uniformly dull. Do not leave any shiny spots in the clearcoat. After sanding, clean and dry the panel and blow off any dust. Once the panel is masked it will be ready for paint.

Melt

A ***melt*** is also known as a solvent blend. It is most commonly used on a sail panel when the quarter panel is repaired. See **Figure 28-58**. A well-executed melt will make the line between the old and new clearcoats invisible. However, a melt is not durable because the clearcoat at the very edge of the melt is thin. For this reason, most paint manufacturers do not recommend a melt.

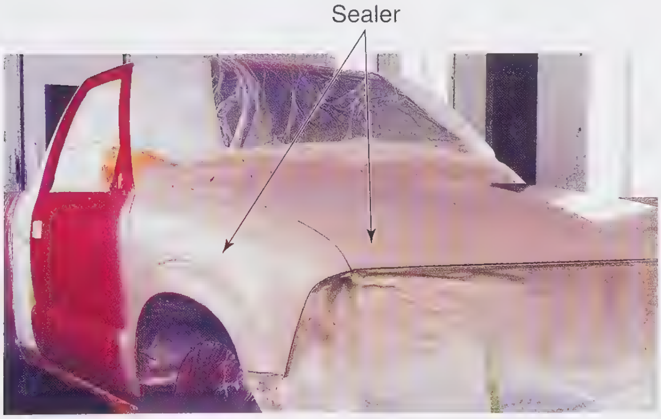


Figure 28-57. *Blending makes a gradual transition from refinish paint to existing paint. The refinish color will be sprayed over the sealer and blended into the door.*

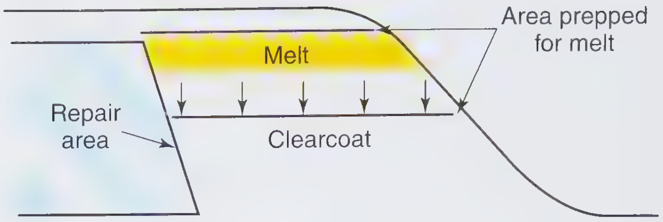


Figure 28-58. *The clearcoat will be melted into the sail panel. Prepping requires scuffing beyond where the melt will be made.*

As in a blend, evaluate the surface, plan the repair, remove obstructions, and clean the panel to remove contaminants. Then scuff the melt area with wet 2000-grit sandpaper. Sand beyond where the clearcoat will end. After sanding, blow off any sanding dust, clean the panel, and mask it for paint.

Trim

Most shops pre-paint inaccessible areas of new replacement parts prior to installation. This is known as ***trimming***, ***edging***, or ***cutting in***. Trimming will paint the areas of a bolted-on part that are inaccessible or difficult to reach after the part is installed. Examples of such areas include the underside of a hood or deck lid, the inside of a door, or the flanges on a fender. Begin by evaluating the surface of the part. Look for dents or runs in the factory E-coat. Clean the part with pre-sand solvent and scuff the primer with a red abrasive pad or 400-grit sandpaper. Some shops sand the entire part at one time. After sanding, blow off sanding dust and clean the part. Apply sealer or epoxy primer and allow enough time to flash off. Then apply basecoat and clearcoat. **Figure 28-59** shows a trimmed replacement part.

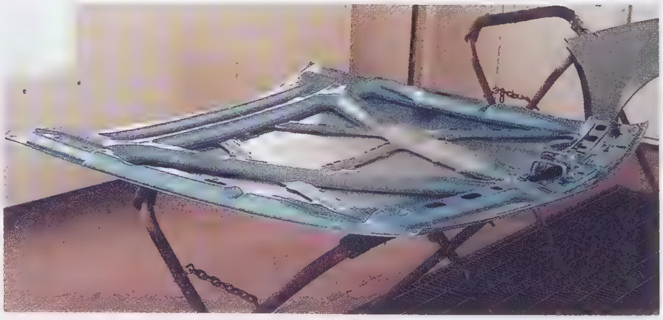


Figure 28-59. *Trimming means painting the areas of a bolted-on part that are inaccessible or difficult to reach after the part is installed. The underside of this hood and the hidden areas of the fender have been trimmed.*

Summary

- Topcoat quality is dependent on the thoroughness of surface preparation.
- For maximum durability, all obstructions should be removed from a panel prior to painting.
- Carefully inspect the surface before repainting.
- It is much easier to mask a surface than to remove overspray. Mask thoroughly.
- Featheredge all broken paint areas with 80-, 180-, and 320-grit sandpaper.
- Treat bare metal with acid wash and conversion coat or self-etching primer.
- Use an epoxy primer on treated bare metal.
- Use surfacer to fill featheredged areas.
- Block sand all filled areas until flat.
- Prepare both sides of a welded panel.

Review Questions

Please do not write in this textbook. Place your answers on a separate sheet of paper.

1. A door is to be repainted; maximum durability is required. The door handle, rearview mirror, and belt molding should be removed. True or False?
2. Paint should be stripped off if the surface has more than ______ mils of paint.
3. The recommended grit sequence of sandpapers to use when featheredging is 80-, 180-, and 320-grit. True or False?
4. A paint surface has cracking. The surface can be scuffed and repainted. True or False?
5. Water is used to remove oil soluble contaminants. True or False?
6. Chemical stripping will remove just the upper layer of paint, leaving the undercoat unharmed. True or False?
7. Sand blasting creates so much heat that it can easily ______ low-crown panels.
8. Chemical stripping, scraping, and sand blasting are all effective methods for the removal of peeling paint. True or False?
9. Ridges and valleys created by sanding allow new paint to ______.
10. A vehicle with OEM paint only has been stripped to bare metal with an 80-grit disc on a DA. The next step is to ______.
11. At minimum, 1/2" of each paint layer should be visible in a featheredge. True or False?
12. ______ taping is where the edge of the masking tape is rolled back.
13. Liquid mask or even a plastic bag can be used to mask a vehicle. True or False?
14. ______ coats of surfacer are usually sprayed on a featheredged area.
15. When bare metal is cleaned with acid, the acid should be allowed to dry on the surface. True or False?
16. A(n) ______ coat is applied to the surface to indicate low spots when block sanding.
17. When surfacer is sprayed, it should remain inside the 320-grit scratches. True or False?
18. When block sanding on a crowned surface, the contour of the panel should be followed. True or False?
19. For isocyanates to crosslink the paint temperature must be at least 60°F (15.5°C). True or False?
20. Orange peel in the clearcoat, visible as shiny dots, will show up as orange peel in the newly applied clearcoat unless it is scuffed to a(n) ______.
21. A tack rag should be rolled into a tight ball and pressed down hard on the surface to remove every last bit of dust before painting. True or False?
22. A nonappearance weld on the inside of a frame rail should be sprayed with self-etching primer. True or False?
23. A melt or solvent blend of clearcoat is not a recommended repair method, according to paint manufacturers. True or False?

ASE-Type Questions

1. A deep scratch in the paint is to be repaired. Technician A wants to evaluate the paint surface first. Technician B wants to featheredge first. Who is right?
   (A) A only.
   (B) B only.
   (C) Both A and B.
   (D) Neither A nor B.
2. All of the following are steps in preparing a body filler repaired panel for a repaint EXCEPT:
   (A) Planning
   (B) Masking for primer
   (C) Block sanding
   (D) Grind welds
3. Technician A says that body filler must be applied over acid-etched bare metal. Technician B says that if no contaminants are seen on a panel, then a pre-paint-solvent wash is not needed. Who is right?
   (A) A only.
   (B) B only.
   (C) Both A and B.
   (D) Neither A nor B.

4. All of the following are ways to prepare clearcoat for a blend EXCEPT:
   (A) Scuff with 1000-grit wet sandpaper by hand
   (B) Scuff with 80-grit sandpaper
   (C) Scuff with 800-grit dry sandpaper on a dual-action sander
   (D) Scuff with a gray scuff pad and sanding paste
5. A replacement fender needs to be trimmed. Technician A wants to scuff the flanges with a red scuff pad. Technician B wants to scuff the flanges with 400-grit sandpaper. Who is right?
   (A) A only.
   (B) B only.
   (C) Both A and B.
   (D) Neither A nor B.
6. All of the following sandpaper grits are used in a featheredging sequence EXCEPT:
   (A) 24.
   (B) 80.
   (C) 180.
   (D) 320.
7. When block sanding, Technician A wants to sand until bare metal is exposed. Technician B wants to sand until the guide coat is removed. Who is right?
   (A) A only.
   (B) B only.
   (C) Both A and B.
   (D) Neither A nor B.
8. Bare metal has been exposed for twenty minutes. Technician A wants to spray the bare metal with epoxy primer. Technician B wants to spray the bare metal with self-etching primer. Who is right?
   (A) A only.
   (B) B only.
   (C) Both A and B.
   (D) Neither A nor B.
9. The OEM paint is peeling. Which of the following methods would be the best way to remove the peeling paint?
   (A) Grinding.
   (B) Scraping.
   (C) Scuffing.
   (D) Sand blasting.
10. Technician A block sands cured surfacer with 320-grit dry sandpaper. Technician B says that only wet sandpaper should be used to block sand. Who is right?
   (A) A only.
   (B) B only.
   (C) Both A and B.
   (D) Neither A nor B.
11. Which of the following is done before the other steps during surface preparation?
   (A) Featheredge.
   (B) Block sand.
   (C) Plan.
   (D) Mask for primer.
12. Which of the following should be checked for when inspecting a surface prior to refinishing?
   (A) Peeling.
   (B) Repaint.
   (C) Cracking.
   (D) All of the above.
13. A roof has 12 mils of paint. The roof needs to be repainted. Technician A wants to sand and repaint. Technician B wants to strip off the roof to the bare metal. Who is right?
   (A) A only.
   (B) B only.
   (C) Both A and B.
   (D) Neither A nor B.
14. A vehicle has OEM paint only. The hood needs to be stripped. Which grit of sandpaper is the best to use in this application?
   (A) 24.
   (B) 36.
   (C) 80.
   (D) 400.
15. An inaccessible area of a unibody frame rail has been welded. Technician A says that since the area is not accessible, it does not need to be prepped and primed. Technician B wants to prep it by removing weld scale with a blow gun. Who is right?
   (A) A only.
   (B) B only.
   (C) Both A and B.
   (D) Neither A nor B.

Chapter 29

Color Matching

Objectives

After studying this chapter, you will be able to:

- Explain how wavelength absorption determines color.
- Explain why colors appear different under various light sources.
- Describe the qualities of a color: hue, value, and chroma.
- Demonstrate how to view a color.
- Explain how to plot a color.
- Demonstrate how to make a comparison panel.
- Explain what a spectrophotometer does.
- List how spraying factors change colors.
- Explain how to tint a color.

Technical Terms

additive tinting
cast
chroma
color wheel
color-corrected lightbulbs
face/head on
flop
hue
mass tone
metamerism
near-spec
pitch
primary hue
secondary hue
side tone
spectrophotometer
subtractive tinting
tinting
tinting chart
value

Introduction

This chapter explains the art of color matching. As stated previously, the refinish paint is the first aspect of vehicle repair the customer sees. To the customer, a difference in the color between the original paint and the refinish paint is an obvious sign of a poor repair. Color matching is an art and requires a great degree of skill. Any differences in color between the refinish paint and the original paint must be identified. When the differences are identified, the painter must manipulate the refinish paint to look more like the original paint.

Color Description

About 100 years ago, Albert Munsell devised a system to describe color. He broke color down into three separate and distinct qualities: hue, value, and chroma. He then organized these three qualities in a three-dimensional color tree. Each quality is explained as a separate subject in the following section. The combination of qualities used to make the color tree will then be discussed.

Hue is the name of the color. For example, red is a hue. The ***primary hues*** are red, yellow, and blue. If the hues yellow and blue are combined, the result is green. Most color charts used in automotive refinishing show four, not three, primary hues. The primary hues used in automotive refinishing are red, yellow, green, and blue. These hues are shown as a color wheel in **Figure 29-1**.

Secondary hues are shown between the primary hues. If one part of blue is added to one part of red, you get violet, a secondary hue. All the secondary hues in the circle are a one-to-one combination of their adjacent primary hues. A secondary hue is sometimes called tone or shade. Of the eight primary and secondary hues; violet, blue, green, yellow, orange and red are considered the "visible huges."

Value is the lightness or darkness of a color. Value is about light intensity. A value scale is shown in **Figure 29-2**. This scale has white at the top and black at the bottom. Light colors have high value, while dark colors have low value. Various shades of gray are located between the highest and the lowest value. Colors can be light, such as pink. Adding white to red increases the value of the red, making it pink. Adding black to red decreases the value of the red, making it brown. Value is also known as whiteness or blackness. A white, black, or gray color has a minimum of hue.

Chroma is the intensity or brilliance of a hue. Chroma can also be described as the contrast between dull and vivid. A highly chromatic color is pure, without the addition of white and black. Neutral gray is made of equal parts white and black. Neutral gray has no hue or chroma. As neutral gray is added to a color, intensity decreases. A chroma scale is shown in **Figure 29-3**. Chroma is also called saturation, richness, or clean/dirty.

The three qualities of color are visually displayed in a color tree, **Figure 29-4**. Think of the color tree as a wheel or a flat disk, with a three-dimensional cone pointing up on the top and another cone pointing down at the bottom. Hue is around the perimeter of the disk.

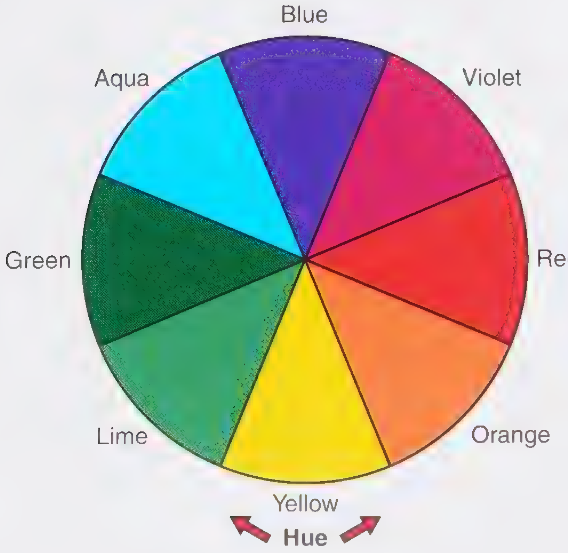


Figure 29-1. *Hue is another word for color. (PPG)*

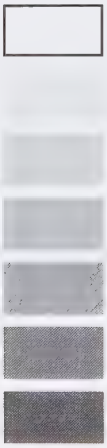


Figure 29-2. *Value is the relative lightness or darkness of a color sample. (GretagMacbeth)*

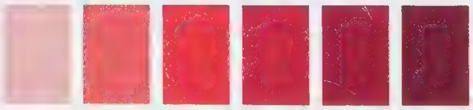


Figure 29-3. *Chroma is the intensity or brilliance of a color sample. Another word for chroma is saturation. (GretagMacbeth)*

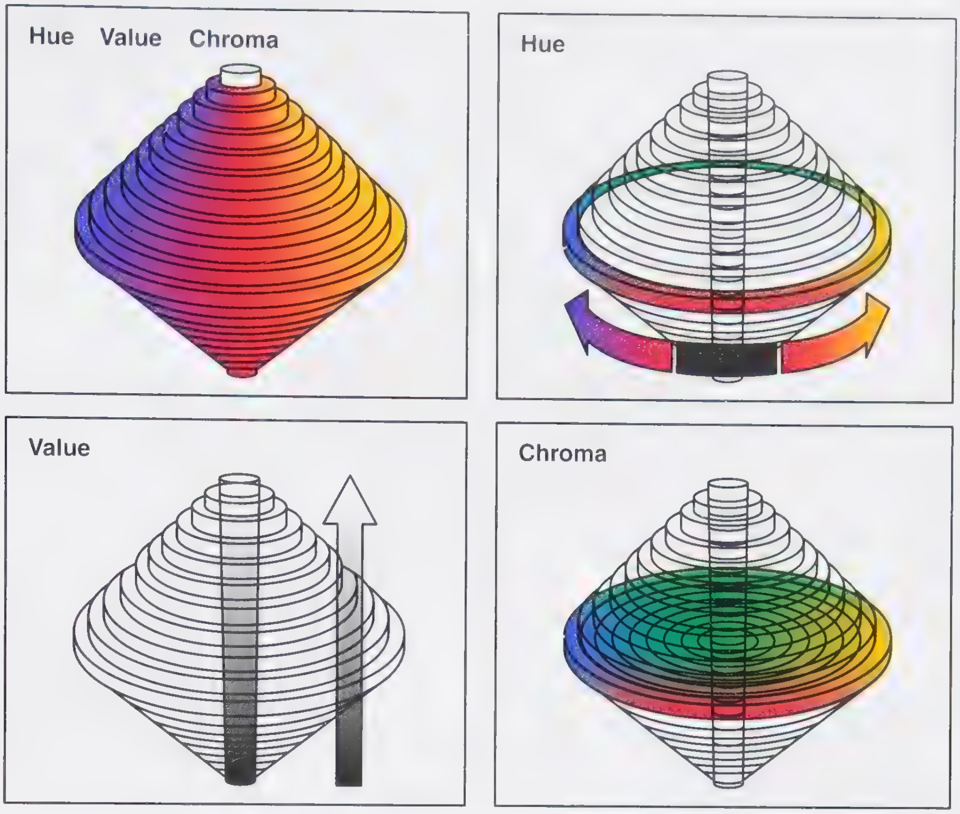


Figure 29-4. *The three qualities of color—hue, value, and chroma—are visually displayed in a color tree. (Toyota)*

Value is a post running through the color tree from the point of one cone down to the other. Chroma extends from the post to the perimeter.

Color can be plotted on the tree. A color is evaluated for hue, value, and chroma, and placed in the appropriate location on the color tree. This is a big help when comparing colors for color matching.

The color tree not only locates the colors around the perimeter—reds, blues and greens, but also combination colors. For example, brown is a combination of red and black. To locate brown, start at the red hue and move inward toward the value post. The same is true for beige. Beige is a lighter shade of brown, which has a higher value than brown. In fact, any color can be plotted on the color tree—even metallic colors.

Adding metallic to a color decreases chroma. When adding metallic, imagine you are adding gray pigment. Metallic colors have low chroma and it is easy to understand how mixing in a metallic will lower the intensity, brilliance, and vividness of the new color. Therefore, metallic colors are not plotted at the perimeter, but instead are near the center of the color tree. A silver color, which is primarily metallic and almost neutral gray, is near the post on the color wheel. Silver has low chroma.

Light and Color

Colors used on today's vehicles can be solid (pigment only), metallic (aluminum flakes and pigment), or pearl (translucent mica particles and pigment). Automotive paint colors can also be a combination of pigment, metallic flakes, and translucent mica particles. The difference between colors should be evaluated in natural light rather than artificial light. The light source a color is viewed under determines the appearance of the color.

Light

The average person can distinguish about 150 colors (all of them based on the six visible hues in the spectrum: red, orange, yellow, green, blue, and violet). The color of an object is determined by the wavelengths of light reflected by the object. Visible light from the sun is in the wavelength range of 400–700 nanometers, **Figure 29-5**. Pigment in a vehicle's paint absorbs some of these wavelengths of light and reflects others. The reflected wavelengths are what our eyes perceive as

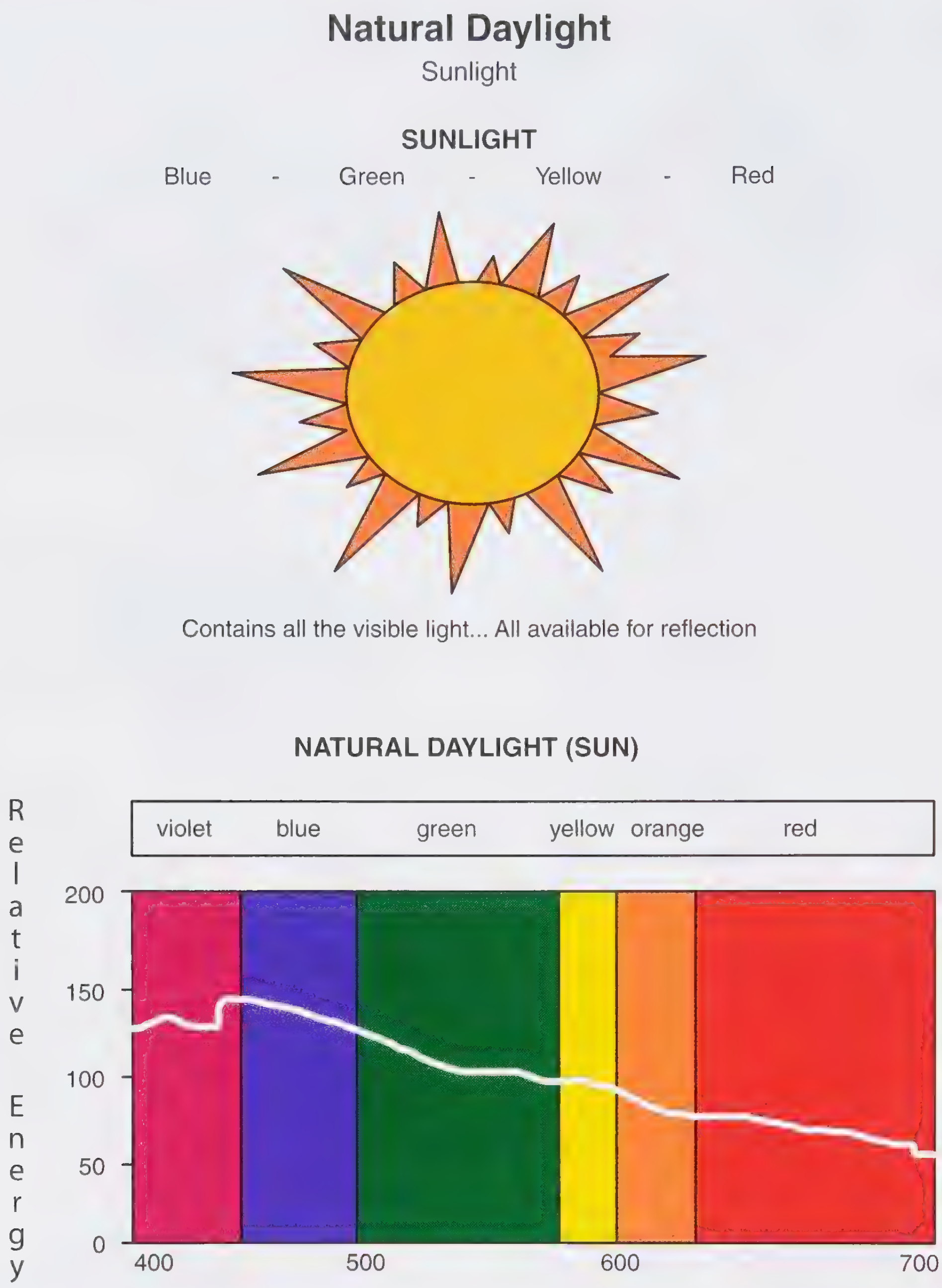


Figure 29-5. *Visible light from the sun contains the colors violet, blue, green, yellow, orange, and red. (PPG)*

the color of the object. For example, the pigment in the paint on a green vehicle absorbs the violet, blue, yellow, orange, and red wavelengths, but it reflects the green.

White pigment reflects all wavelengths, while black pigment absorbs all wavelengths. If a white vehicle and a black vehicle are placed in sunlight, the surface of the black vehicle will feel warmer than the surface of the white vehicle because the black vehicle absorbs all wavelengths of light. The white vehicle reflects all light wavelengths and, therefore, does not heat up as much.

Light Sources

Our perception of color is entirely dependent on the light source it is viewed under. Natural sunlight contains a specific balance of wavelengths. For color matching, natural daylight from the north is used as the standard. Artificial light, such as fluorescent and incandescent light, contains a different balance of wavelengths. Due to these different balances, colors will appear slightly different when viewed under different light sources. If a green object is viewed under incandescent light, which is deficient in green, blue, and violet wavelengths, the true color of the object will not be seen. Ordinary fluorescent lights have sharp peaks in the violet and green wavelengths. **Figure 29-6** shows how colors can change, depending on the light source.

Color-corrected lightbulbs are available for use in the spray booth. These bulbs produce light with a wavelength balance similar to natural light. Looking at a vehicle under color-corrected light will provide the true color.

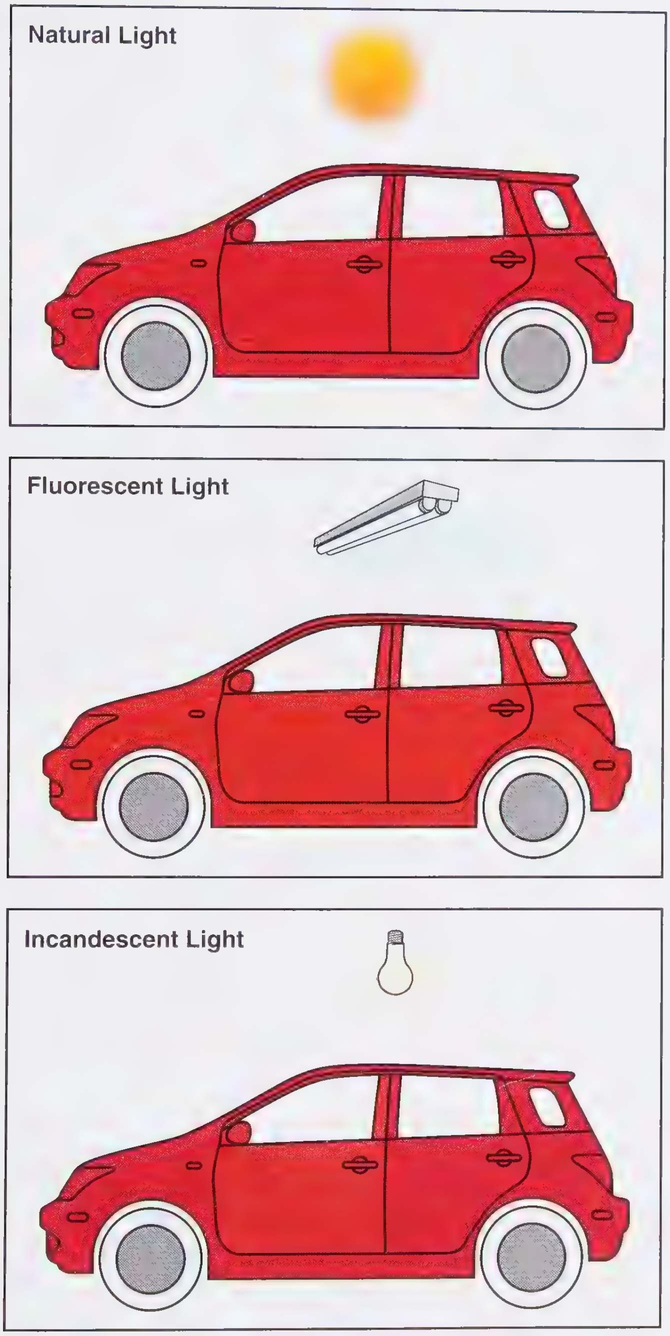
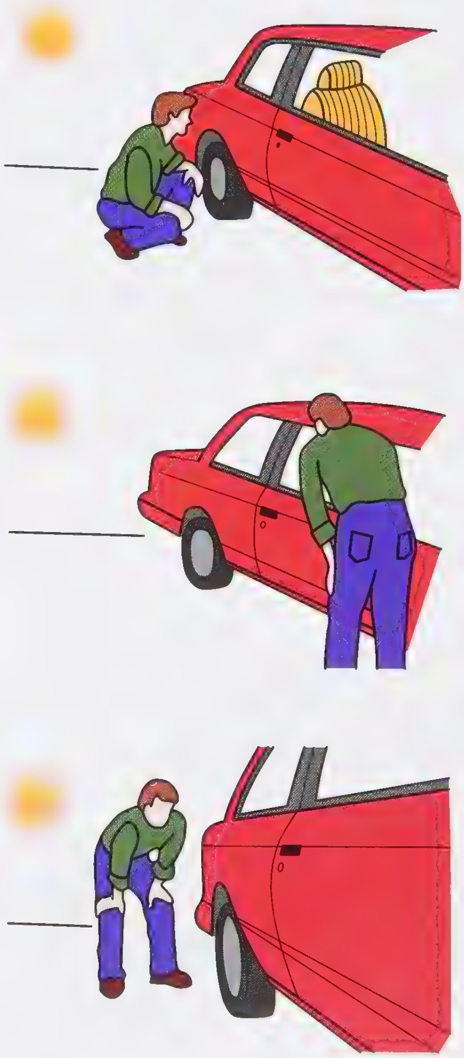


Figure 29-6. *The light source a color is viewed under determines the appearance of the color. Always match the color under natural light.*

If color-corrected lights are not available, evaluate colors outside in natural light. Looking at colors under incandescent lighting or fluorescent lights that are not color corrected will give a false impression of the color. For accurate color matching, this cannot be stressed enough.

How to View a Color

Colors can be viewed either straight on or from an angle. The straight-on view of a vehicle is called ***face***, or ***head on***. Viewing the vehicle at an angle is called ***pitch***. Pitch can be broken down into two views: ***near-spec*** and ***side tone***. In the side tone view, the sun is behind you as you look down the side of the vehicle. In the near-spec view, sun is in front of you as you look at the side of the vehicle. See **Figure 29-7**.



Head On
Viewing the repaired area at an angle that is perpendicular to the vehicle

Near-spec
Viewing the repaired area at an angle less than 45 degrees with the sun in front of you

Side Tone
Viewing the repaired area at an angle of less than 45 degrees with the sun behind you

Figure 29-7. *Colors can be viewed either straight on or from an angle. (Dupont)*

Colors

As discussed previously, a vehicle's color is produced by the wavelengths of light reflected by the pigment. A light color (a hue with a high value) reflects more wavelengths than a dark color. In solid color paint, the pigment is composed only of color tints, and light is absorbed and reflected by the pigment. **Figure 29-8** shows a diagram of solid color.

In a metallic color, **Figure 29-9**, the paint film contains both pigment and metallic flakes. With metallics, light is absorbed and reflected by the pigment just like a solid color, but the metallic flakes act like mirrors, and they too reflect light. One would think that metallic colors are more intense than solid colors, but when metallic flakes are added to a color, the color becomes less intense because the metallics are gray, and adding gray reduces a color's intensity.

Different sizes of aluminum flakes are available. In general, larger flakes produce a lighter finish than smaller flakes. The orientation of the flake in the paint film also has an effect on the lightness or darkness of the color. **Figure 29-10** shows a normal distribution of pigment and flakes. When looking at the paint, the surface has a random arrangement of pigment and flakes. **Figure 29-11** shows an arrangement where the flakes are crowded at the surface. This causes the flakes to reflect light, and not as much of the pigment can be seen. **Figure 29-12** shows the opposite condition. The metallic flakes are at the bottom of the paint layer with pigment on top. In this color, more pigment and fewer flakes are seen. The overall affect is darker.

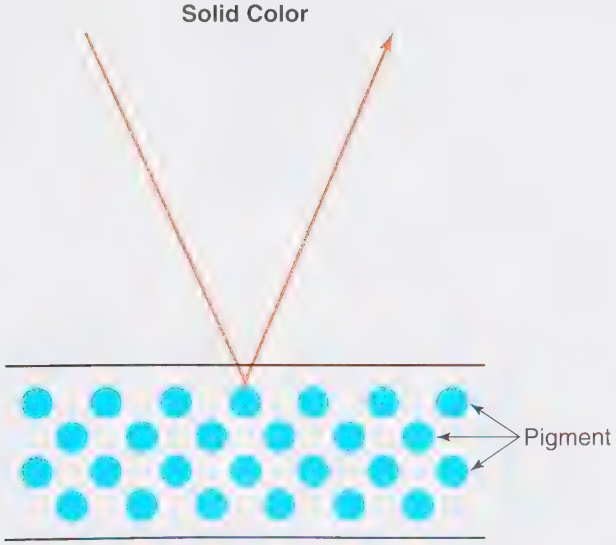


Figure 29-8. *Color is determined by the wavelengths of light reflected by the object. In a solid color, the pigment absorbs all other wavelengths, but reflects the wavelength of the color that we see. (Toyota)*

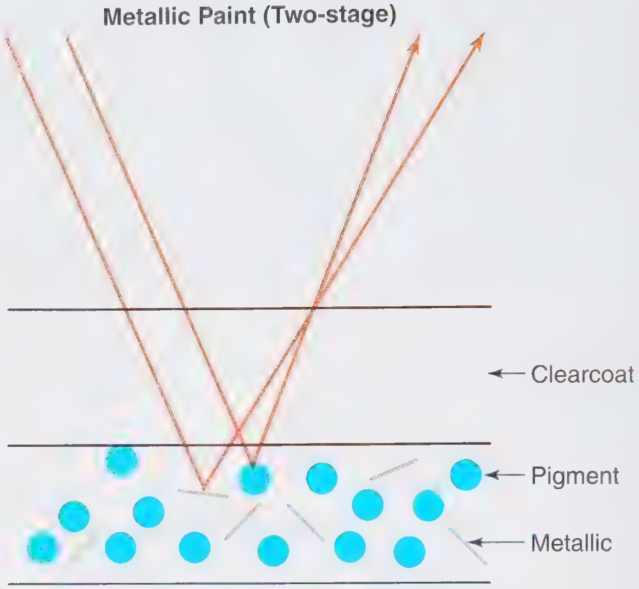


Figure 29-9. *In a metallic finish, both pigment and metallic particles influence the color. (Toyota)*

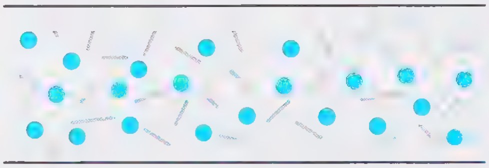


Figure 29-10. *This is a normal distribution of aluminum flakes; the flakes are randomly distributed among the pigment. (Toyota)*

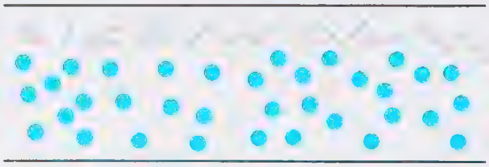


Figure 29-11. *The flakes are crowded near the surface; less pigment is seen and the final color appears lighter. This is typical of dry paint application. (Toyota)*

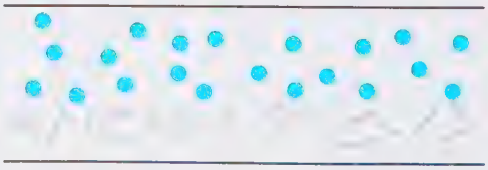


Figure 29-12. *The flakes are sunken near the bottom; more pigment is seen, and the final color appears darker. This is typical of wet paint application. (Toyota)*

Pearl, which is made from mica flakes, is translucent. Like aluminum flakes, the mica flakes reflect light. However, they also allow some light to pass through. The light passing through the mica flakes reveals some of the pigment, producing a subtle, glowing effect.

A tricoat, shown in **Figure 29-13**, consists of three distinct layers: a basecoat, a pearl midcoat, and a clearcoat. The number of pearl midcoats and the color of the basecoat determine the appearance of a tricoat. A common type of tricoat consists of a solid white basecoat and two coats of pearl. A less common type of tricoat uses a metallic basecoat, pearl midcoat, and clearcoat.

A variation of the tricoat consists of a metallic and pearl basecoat, a tinted clear midcoat, and a clearcoat. The midcoat does not contain pearl like a tricoat. The tinted midcoat subtly influences the appearance of the underlying basecoat.

Why Colors Do Not Match

If paint is to match, there must be no visible difference between the color of the refinish paint and the color of the vehicle paint. In other words, the colors must look the same. One aspect of vehicle repair that customers and new students may not realize is that even when paint code numbers match, the refinish paint often does not match the paint color on the vehicle.

WORKING SMART

A slight mismatch in color can be hidden with skillful blending. Blending will be discussed in more detail in Chapter 30.

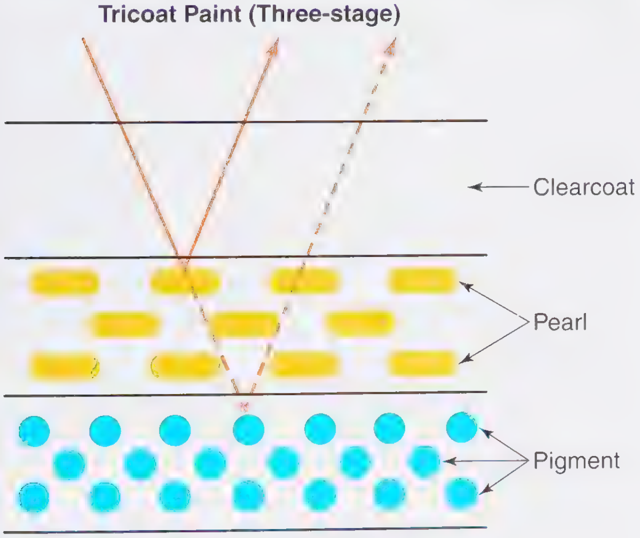


Figure 29-13. *Translucent mica in the pearl midcoat reflects some light, but it allows some light to pass through to reflect off the pigment below. Pearl produces a subtle, glowing effect.*

The reasons refinish colors may not match the vehicle color include the following:

- Vehicles are painted at the factory with a type of paint that is different from the type of paint available to refinishers.
- Vehicle manufacturers buy paint from many different manufacturers. Each manufacturer has its own formula for each particular color.
- The environmental and spraying conditions are different at each vehicle factory and may vary from one day to the next.
- A vehicle color sprayed at the factory may be influenced by the color of the previous vehicle on the assembly line.
- Paint suppliers mix refinish color to match an OEM standard. If the OEM standard is not representative of the vehicle to be repainted, the refinish paint color will not match.

These are just a few reasons colors do not match. They do not include all the variables that come into play at the refinish level. For example, a vehicle may have been repainted previously in a color that did not match the factory finish. The following sections will explain how to perceive a color difference and what to do if a color difference is present.

NOTE

Our perception of color depends on the ability of our eyes to distinguish colors. The most common defect in color vision is called red-green color blindness. In red-green color blindness, an individual cannot see a difference in color between a green object and a red object. This defect affects about 7% of all men and 1% of all women. There are other, less-common types of color blindness. A chart similar to the one shown in Figure 29-14 can be used to check for color blindness. An individual with a defect in color vision will have a difficult time distinguishing between some colors.

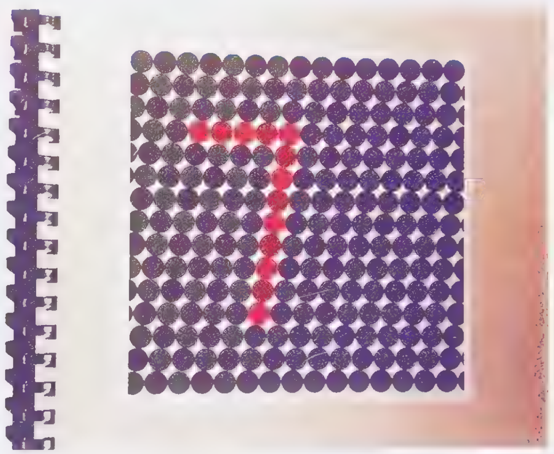


Figure 29-14. *The most common defect in color vision is called red-green color blindness. This is a color blindness test chart.*

Comparing Two Colors

When refinishing a vehicle, there will always be two colors that must be taken into consideration — the refinish paint color and the vehicle color. If the refinish color is close enough to the vehicle color for a satisfactory blend, no further work on the color is needed. However, if the refinish color is not close enough for a blend, the technician must determine which quality or qualities (hue, value, and chroma) of the refinish color are different from the vehicle color. Then the technician must decide how to modify the refinish color to make it match the vehicle color.

The comparison of colors and the analysis of the differences between them are the most difficult parts of color matching. Once the differences are identified, steps can be taken to make the necessary changes. However, seeing the difference is much easier than explaining exactly what that difference is. Therefore, you should use the hue portion of the color tree, which is called a ***color wheel***, when describing color differences. A hue can be influenced by adjacent hues. This subtle presence of an adjacent hue in a color is called ***cast***. A red can be described as being too yellow or too blue. A green can be described as too yellow or too blue. A blue can be described as too green or too red. A yellow can be described as too green or too red. Always describe the refinish paint in comparison to the vehicle color. For example, if a red car is to be repainted and the refinish paint is compared to the vehicle color, the painter could say the refinish paint is more yellow than the vehicle paint. (Remember that yellow and red combined make orange.) The painter can describe the refinish paint as slightly orange when compared to the vehicle color. If the vehicle color is blue, for example, the refinish paint may be either too green or too red when compared to the vehicle.

High value colors, such as white or light silver, or low value colors, such as black or dark silver, may have a slight amount of any hue. For example, a white can have a slight yellow, green, or red hue. Even a black can have a brown or yellow hue. Look at the color tree. At the point of the top cone, the lightest, highest value color is pure white. Adding any hue will change the color, decreasing value (the relative lightness or darkness of a sample). The same is true at the point of the bottom cone; the darkest, lowest value color is pure black. Adding any hue will change (increase) the value.

Single-stage paints and some basecoat/clearcoat paints will fade with age. Ultraviolet light from the sun acts on the pigments in the paint, causing them to lose intensity. Always clean and hand rub the vehicle with compound to make sure the color is true. Hand rubbing with compound will remove faded single-stage paint, giving you a true indication of the color.

Metallics may show flop. ***Flop*** is a condition in which the comparative lightness or darkness of a color changes as the viewing angle changes. Therefore, metallics should be viewed from every angle — face, near-spec, and side tone. For example, refinish metallic color may look light compared to the vehicle paint when viewed from near-spec, but the refinish paint may look darker in side tone. Flop is caused by a difference in the metallic flake orientation between the refinish paint and the vehicle color. The face may match, but the pitch is off. Always check metallics for flop.

The following characteristics should be considered when comparing refinish paint to vehicle color:

1. Is the hue (color) of the refinish paint different from the hue (color) of the vehicle? If so, how does it differ?
2. Is the refinish paint lighter or darker (higher or lower value) than the vehicle color? If it is, how much lighter or darker is it when compared to the vehicle color?
3. Is the refinish paint as intense (chroma) as the vehicle color? If not, is it more intense or less intense?
4. Are the metallic flakes in the refinish paint the same size as those in the vehicle color? If not, what size are the metallic flakes in the original vehicle color?

Alternate Formulas

Two vehicles with exactly the same paint codes may differ slightly when compared side-to-side. Paint manufacturers recognize this. To help refinishers match colors, paint manufacturers develop alternate formulas for the same paint code. These alternate formulas are matched to the most common variations in vehicle color.

A paint code may have ten or more alternate formulas. See **Figure 29-15**. The alternate formula colors are often described by how they differ from the color chip in a paint book. The manufacturer will refer to the color chip as the prime or standard. An alternate would be compared and described as: “lighter than the color chip”, or “more yellow than the standard”, or “bluer than prime”.

A deck of alternate color chips is shown in **Figure 29-16**. These color chips can be compared to the vehicle color. If an alternate color is a match, it can be mixed and a comparison panel can be sprayed. If an alternate deck is not available, the color chip can be compared to the vehicle and the alternate color description that best matches the vehicle color can be used.

Comparison Panel

A comparison panel is used to check for color match. To save on paint, some shops mix a tenth of a quart for comparison purposes. To do this, use tint weights for a quart of paint and move the decimal points one place to the left.

U7–56742 00(Y) SANDRIFT MET (BC)	
CODE:	**1 Gallon OF 1**
U7011 BC F METALLIC	2325.0
U7001 MET NO 2	2794.9
U7118 BLACK	3238.5
U7003 WHITE MICA	3440.2
U7136 H S MAROON	3520.4
U7110 S WHITE	3554.3

U7–56742 01(Y) SANDRIFT MET (BC)	
CODE:	**1 Gallon OF 1**
PT17 COPPER PEARL	41.0
J7109 CLEAR	218.8
J7011 BC F METALLIC	3193.8
J7118 BLACK	3340.9
J7136 H S MAROON	3361.4
J7135 H S IN BLUE	3378.5
T1F271 EX FL BASE	3583.6

Figure 29-15. *A single paint code may have ten or more alternate formulas. Here are two paint formulas for the same paint code. (Sherwin Williams)*

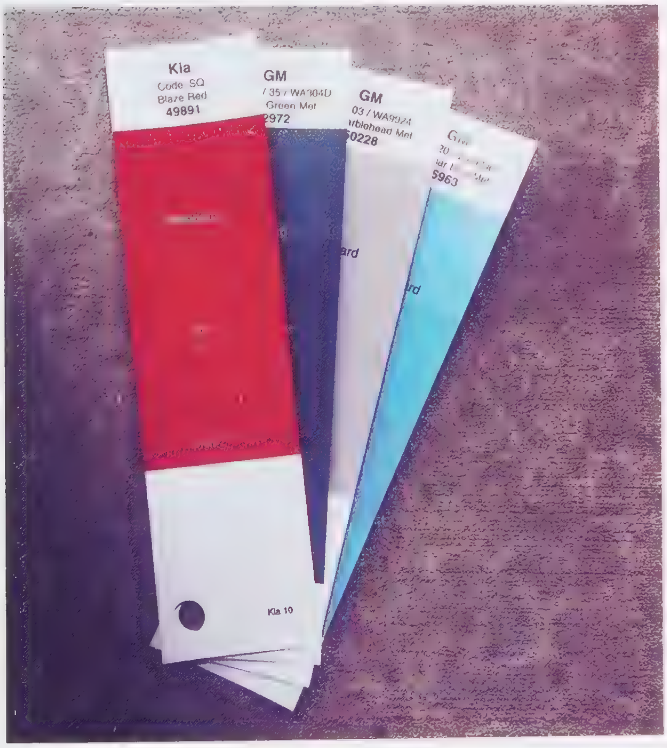


Figure 29-16. *These alternate decks show the standard color and the alternates. These colors can be compared to the vehicle to see which is the best match.*

In an ideal situation, the paint is mixed and a comparison panel is made as soon as a vehicle is brought into the body shop. By mixing and comparing early in the repair process, the painter has time to alter the color before the vehicle gets into the paint shop. In a worst-case scenario, the vehicle is painted and only after curing is a mismatch discovered. Checking color ahead of time prevents tying up the spray booth trying to match a color. The following section details the procedures for making a single-stage or basecoat/clearcoat test panel, as well as a letdown panel for a tricoat.

Test Panel

To make a test panel, tape a black-and-white coverage chart to the spray booth wall. A test panel is shown in **Figure 29-17**. The paint is reduced with the same type of reducer that will be used when the vehicle is painted. The air pressure should be the same as it will be when the vehicle is sprayed. In fact, the painter should try to make every aspect of spraying the test panel the same as it will be when the vehicle is sprayed. Use the same number of coats, flash time, distance, and overlap. Apply as many coats as are necessary to completely cover the black-and-white squares of the coverage chart. Once the basecoat has flashed, the test panel must be clearcoated.

A paint technician's goal is to match the color and texture of the paint already on the vehicle. Layers of paint can impart a subtle influence on the final color. By comparing a test panel to the vehicle, a technician will know how many coats of paint are needed for an accurate match, and if the color is right. Creating a test panel is a time-consuming process, as it involves mixing and applying basecoat and clearcoat, as well as cleaning the spray gun. Even so, a test panel is cheap insurance when compared to doing the job over.

Figure 29-17. *This is a test panel. The painter should try to make every aspect of spraying the test panel the same as it will be when the vehicle is sprayed. Use the same number of coats, flash time, distance, and overlap.*

A drawdown bar is shown in **Figure 29-18**. The color created with a drawdown bar is approximate rather than exact. However, using a drawdown bar is much faster than spraying a test panel. A drawdown bar is used to spread unreduced paint on a sheet of clear plastic. A coverage chart is kept under the plastic. When the black-and-white on the coverage chart can no longer be seen, hiding is complete. The clear plastic takes the place of clearcoat. The shiny side of the plastic, where the basecoat has not been applied, is compared to the vehicle paint.

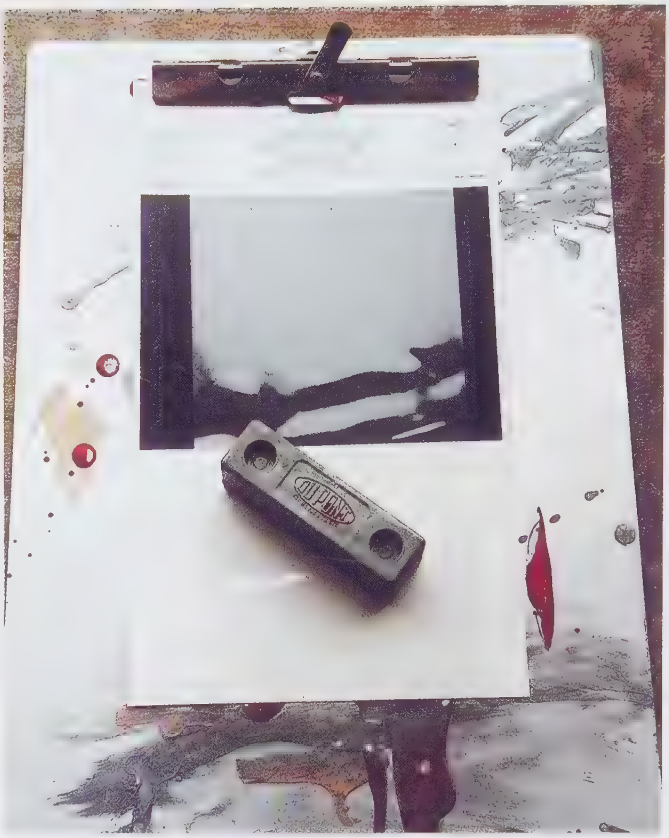


Figure 29-18. *The drawdown bar is used to spread unreduced paint on the clear plastic sheet. The black and white coverage chart will show when coverage/hiding has been achieved. The clear plastic acts as a clearcoat.*

NOTE

Some painters spray the base coat to cover the test panel and then, instead of mixing and spraying clearcoat, apply wax-and-grease remover to the panel to simulate a clearcoat. The test panel is placed on the vehicle and the wax-and-grease remover is poured on the panel.

Letdown Panel

A letdown panel is created to color match a tricoat. **Figure 29-19** shows how a letdown panel is made. The panel is divided into five sections, and each section has a left and a right side. Basecoat is sprayed on the entire letdown panel to the point of hiding. Once the basecoat dries, the bottom section of the panel is masked off. One coat of pearl is sprayed on the panel. Once the pearl has dried, the second section from the bottom of the panel is masked off and another coat is sprayed. This sequence of masking and spraying continues until the last section of the panel has been sprayed with four coats of pearl.

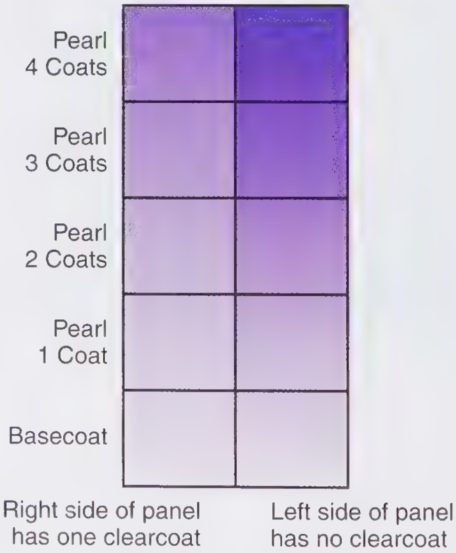

Pearl 4 Coats
Pearl 3 Coats
Pearl 2 Coats
Pearl 1 Coat
Basecoat
Right side of panel has one clearcoat
Left side of panel has no clearcoat

Figure 29-19. *A letdown panel is created to color match a tricoat. It is used to compare the refinish basecoat to the vehicle and also to determine how many coats of pearl are required for color match. (Toyota)*

After the last coat of pearl has dried, the left side of the panel is masked off and the right side is sprayed with one coat of clear. When completed, the letdown panel is used to compare the refinish basecoat to the vehicle and also to determine how many coats of pearl are required for color match.

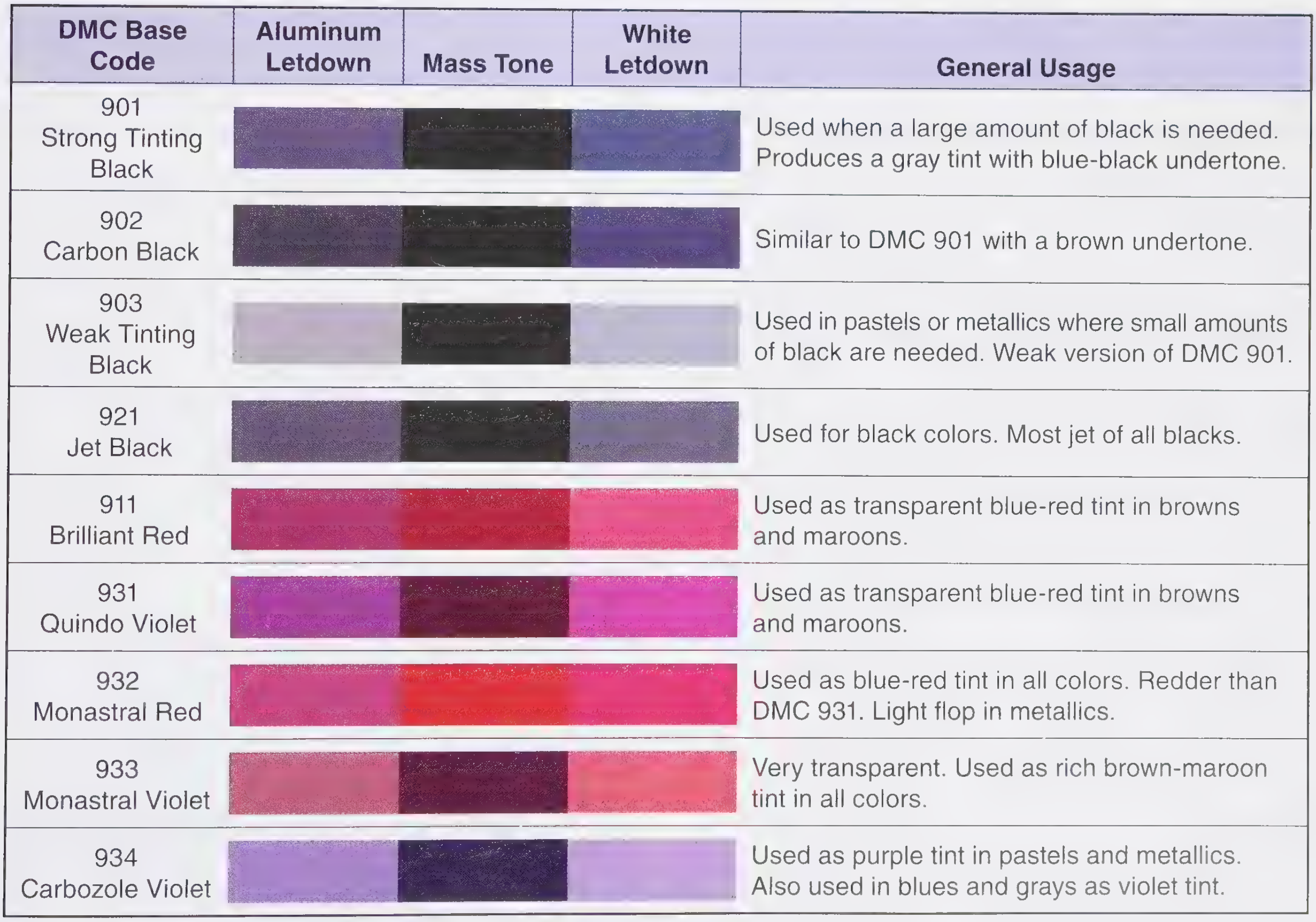
Plotting a Color

Locating two different colors on the color tree will show the painter exactly how the colors are different. Color plotting is like making a road map. By plotting the colors, the painter knows which direction to take if refinish paint must be altered to match the vehicle color. To plot colors, the painter compares the test panel to the vehicle.

Plotting the refinish color is easier when an existing paint formula is used. Look at the name and amount of each tint. The technician checks the formula to see how much of each tint is used. The technician looks at the tinting chart to see the effect of each tint. Seeing the amount of and effect of each tint will help determine where to plot the color.

Figure 29-20 shows a ***tinting chart***. This chart shows the color of each tint. The tint's ***mass tone*** is so dark that the technician cannot simply look at the tint and decide whether or not to use it. Mass tone is the color of the tint if it were sprayed onto a test panel. Letdown is the color of the tint when mixed with metallic (aluminum) or white. The typical ratio is 10% tint mixed with 90% white or metallic (aluminum). A tinting chart shows two letdowns for each tint. One letdown is the tint mixed with metallic and the other letdown is the tint mixed with white. Letdowns show the undertone of the tint. For example, a red tint may have a blue undertone and a blue tint may have a red undertone. Letdowns show the painter how a tint will influence a color.

The position of the plotting is subjective. **Figure 29-21** shows a refinish paint (P) and vehicle color (C) plotted on a two-dimensional color wheel. The two-dimensional color wheel includes two qualities of color: hue and chroma. The refinish paint and vehicle color could also be plotted into a three-dimensional color tree.



DMC Base Code	Aluminum Letdown	Mass Tone	White Letdown	General Usage
901 Strong Tinting Black	🟪	⬛	🟦	Used when a large amount of black is needed. Produces a gray tint with blue-black undertone.
902 Carbon Black	🟪	⬛	🟪	Similar to DMC 901 with a brown undertone.
903 Weak Tinting Black	⬜	⬛	⬜	Used in pastels or metallics where small amounts of black are needed. Weak version of DMC 901.
921 Jet Black	🟪	⬛	🟪	Used for black colors. Most jet of all blacks.
911 Brilliant Red	🟥	🟥	🟥	Used as transparent blue-red tint in browns and maroons.
931 Quindo Violet	🟪	🟥	🟪	Used as transparent blue-red tint in browns and maroons.
932 Monastral Red	🟥	🟥	🟥	Used as blue-red tint in all colors. Redder than DMC 931. Light flop in metallics.
933 Monastral Violet	🟥	🟫	🟥	Very transparent. Used as rich brown-maroon tint in all colors.
934 Carbozole Violet	🟪	⬛	🟪	Used as purple tint in pastels and metallics. Also used in blues and grays as violet tint.

Figure 29-20. *A tinting chart shows the mass tone, the tint mixed with white and the tint mixed with aluminum. This will give the painter an idea of how the tint will affect color. (PPG)*

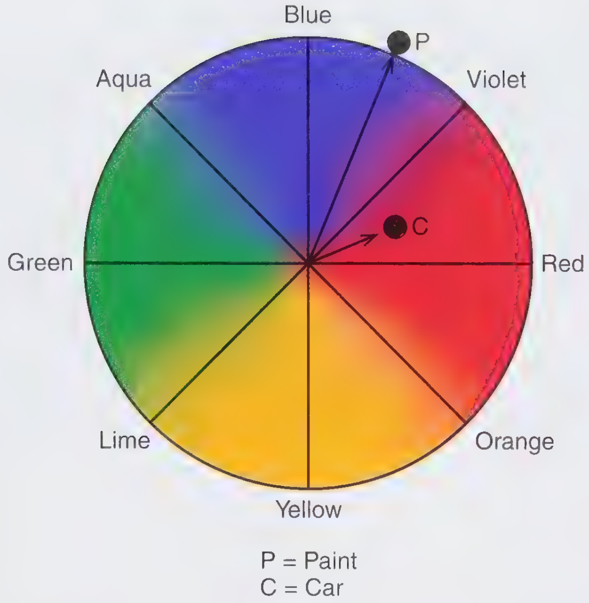


Figure 29-21. *This color plot shows a mismatch between the car and the paint. This two-dimensional color wheel plots two color qualities: hue and chroma. (PPG)*

In the example depicted in **Figure 29-21**, the plotted refinish paint and the vehicle color are not close. Notice that the refinish paint needs to be moved toward red in hue and the chroma needs to be decreased. Through the use of tints, refinish color can be shifted slightly in hue, value, or chroma to match the vehicle color.

Spectrophotometer

A ***spectrophotometer*** is an electronic device that determines the color of a vehicle by measuring light intensity (energy) reflected from a sample. When evaluated with the human eye, colors are subjective. For example, a specific blue could be described as being slightly "redder" than another. A spectrophotometer does not use subjective description to rate a color. Instead, the machine examines and assigns a number value to each color quality—hue, value, and chroma. Four or five readings should be taken on flat surfaces. The machine will average these readings when scanning a database of formulas looking for the closest match. If no matching formula is found, the machine can create a formula. Most spectrophotometers must be hooked up to a computer, although stand-alone units do exist.

To use the spectrophotometer, the vehicle's paint is cleaned in four or five areas. There should not be any scratches, dust, or swirl marks on the surface. The machine provides the light and takes readings from various angles. All the operator has to do is calibrate the machine and then hold it on the paint. The spectrophotometer will alert the user when the reading is complete.

A blendable match is usually obtained from the spectrophotometer. However, a test panel should be made to verify the color match.

Altering the Refinish Color

Once the refinish color and vehicle color have been plotted, the painter must determine if any alterations to the refinish color are necessary. The ability to determine how much of a color difference can be disguised by blending can only be gained through experience. If the refinish color is close enough for a blend, no alterations are needed. A blend can hide a slight color difference.

Figure 29-22 shows a test panel positioned next to a vehicle for comparison. A blend can hide this color difference. The following section explains the procedure for altering basecoat/clearcoat paints, but this information also applies to single-stage paint. Tricoats are discussed at the end of this section.

Metallic Orientation

If the refinish color must be altered, it can be accomplished by tinting. For metallic colors only, refinish color can be altered by changing the orientation of the metallic flakes. As stated earlier in this chapter, the appearance of a metallic color is determined by the position of the metal flakes in the paint film. This is especially true in single-stage metallic colors. In basecoat/clearcoat metallic colors, the basecoat paint film is so thin (usually 1 mil) that orientation of the metallic is less of a factor. When spraying, any variable that makes the paint go on drier (reducer type, spray technique, spray gun adjustments) will make a metallic color appear lighter. Conversely, any aspect of spraying that makes a metallic paint go on wetter will make the color appear darker.

Figure 29-22. *This test panel is compared to the vehicle paint. A skillful blend can hide the slight difference in color.*

In a drier paint application, the metallic flakes do not have the opportunity to settle into the paint film. The paint dries quickly, so flakes are trapped near the surface. Metallic flakes are gray and partially block the view of the tint color. With the flakes crowded at the surface, the color appears lighter than the standard. The opposite is true if paint is applied wetter than normal. In a wet paint application, the metallic flakes have enough time to sink to the bottom of the paint film before the paint dries. With the metallic flakes near the bottom of the paint film, more of the tint color is visible. The overall effect is a darker color. The diagram in **Figure 29-23** shows normal orientation of metallic flakes compared with deep (wet paint application) and surface (dry paint application) metallic flake orientation. The factors that affect the color of metalics are summarized in **Figure 29-24**. Try these techniques and adjustments before adding or subtracting tints.

The easiest factors to change are spray gun technique and spray gun adjustment. When altering metallic orientation to improve color match, spray a test panel to see if the change in value (lightness or darkness of the hue) provides an acceptable color match.

Tinting

If a change in metallic orientation does not create an acceptable match, or if there is an unblendable mismatch in a solid color, the color can be altered by ***tinting***. Tinting involves changing the color of refinish paint by adding or subtracting tints. In ***additive tinting***, a specific tint or tints are added to the existing refinish paint. In ***subtractive tinting***, a specific tint or tints in a paint formula are left out when the paint is mixed. In either method, the painter first plots the refinish color and the vehicle color. The painter then decides on the direction to take. One rule of thumb is to begin by changing the quality of color that is "off" by the most. For example, a blue refinish paint is too red compared to the vehicle color. The refinish paint is also darker and more saturated. All three qualities of color are off—hue, value, and chroma—but the hue is off by more than the value or chroma. Therefore, the hue should be adjusted first. Changing hue will affect value and chroma.

In the additive tinting method, a tint would be added to the blue paint to offset the excess red in the paint. In the subtractive tinting method, the blue paint would be mixed, but the red tint would be left out. If there is no red tint in the formula, then the tint that has a slight red cast would be left out of the mix. The cast of a tint can be seen in a tinting chart. A tint will have a hue and may have a cast. For example, a blue tint may be described as having a red face and a red side tone. The face is seen by viewing the tint straight on, while the side tone is viewed from an angle. The red face and side tone are casts. Even though the tint is blue, it has a red component. When plotted, this tint would be placed on the red side of blue.

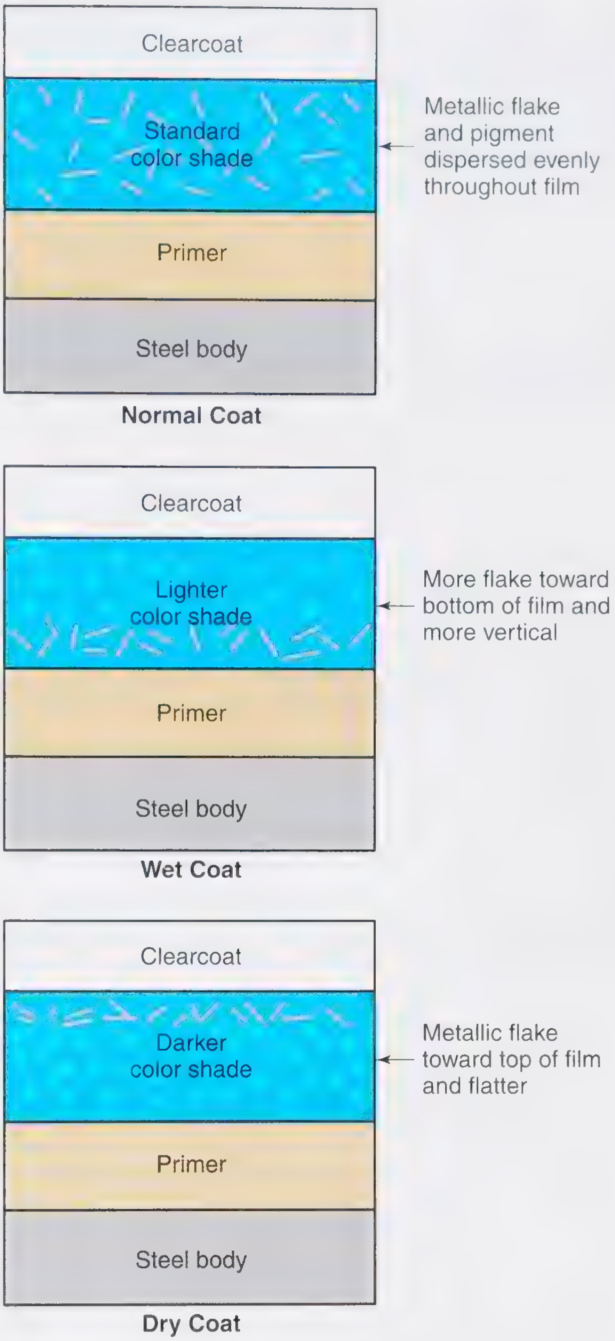


Figure 29-23. *The appearance of a metallic color is affected by metallic flake orientation. (PPG)*

Additive Tinting

Care must be taken when adding tints. Only use tints that are listed in the formula. Adding tints not found in the formula may cause metamerism. ***Metamerism*** is a condition in which two colors look the same under one type of light but look different under another type of light. By only adding tints that are listed in the formula, metamerism can be avoided.

Variables Affecting Color of Metallics		
Variable	**To Make Color Lighter**	**To Make Color Darker**
Shop Conditions:		
Temperature	Increase	Decrease
Humidity	Decrease	Increase
Ventilation	Increase	Decrease
Spray Equipment and Adjustments:		
Fluid cap	Use smaller size	Use larger size
Air cap	Use air cap with greater number of openings	Use air cap with lesser number of openings
Fluid adjustment	Reduce volume of material flow	Increase volume of material flow
Spreader adjustment valve	Increase fan width	Decrease fan width
Air pressure valve	Increase air pressure	Decrease air pressure
Solvent Usage:		
Type of thinner	Use faster evaporating thinner	Use slower evaporating thinner
Reduction of color	Increase volume of thinner	Decrease volume of thinner
Use of retarder	(Do not use retarder)	Add proportional amount of retarder to thinner
Spraying Techniques:		
Gun distance	Increase distance	Decrease distance
Gun speed	Increase speed	Decrease speed
Flash time between coats	Allow more flash time	Allow less flash time

Figure 29-24. *This table lists the variables that affect the color of metallics. (PPG)*

Care should be taken to evaluate the effect of each tint before adding it to the paint. A paint lid can be used to mix a small sample of the refinish paint and tint. See **Figure 29-25**. This will allow the painter to see what effect the tint will have on the paint before mixing a larger quantity. If the effect is not what was expected, then the entire can of paint is not ruined.

Tints not part of the formula, when mixed together, tend to make neutral gray and will decrease the chroma of a color. Carefully choose the tint to do the job. A high-strength tint can cause a striking change in the color. If a high-strength tint is to be added, mixing it 1:1 with clear will lessen its effect.

The addition of tints should be done on a digital scale. In this way, the painter can add a measured amount of tint. Keep a record of the amount of tint added, as this formula may be needed again.

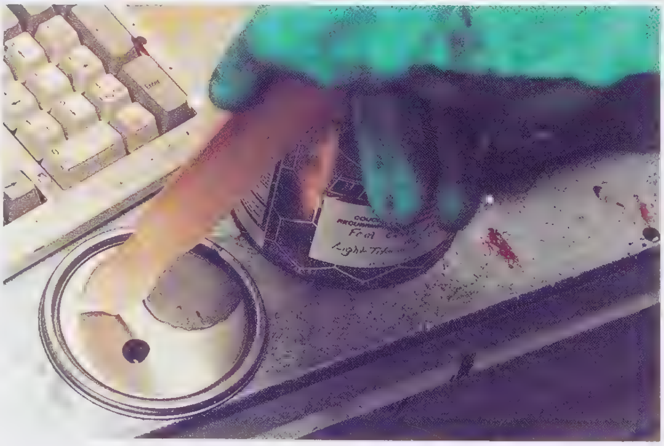


Figure 29-25. *Care should be taken to evaluate the effect of each tint. Add the tint to a small amount of the color to check the effect of the tint.*

To alter a color's hue, plot the refinish color and the vehicle color. If the hue of the paint is unwanted, it must be eliminated. To accomplish this, add a tint from the opposite side of the color wheel. For example, if a blue is too red, a tint from the opposite side of the color wheel—green—will eliminate the red. If there is no green in the formula but there is a blue with a green cast, use this color. However, doing so may decrease chroma.

A tint can also be used to add, rather than eliminate, a hue. Identify the tint in the formula that will move the paint in the correct direction. See **Figure 29-26**. In this example, the blue paint on the car is redder than the refinish paint. There is no red in the formula, but there are two blues—a green-cast blue and a red-cast blue. In this example, adding a red-cast blue tint to the paint would move the refinish paint hue in the correct direction. Plotting colors makes this easier to visualize.

The value (lightness or darkness) of most solid colors can be changed by adding black or white if black and white are in the formula. See **Figure 29-27**. Do not try to change the value of a red color. Adding white to red makes it pink, while adding black to red makes it brown.

To lighten a solid color when there is no white in the formula, add the lightest tint in the formula. The same reasoning applies when darkening a color that has no black in the formula—add the darkest tint in the formula. Look at the letdown on a tinting chart to determine which tints are lightest and darkest. Identify the lightest or darkest tint by what the tint looks like when mixed with white. When adding this tint, both the hue and the chroma may change.

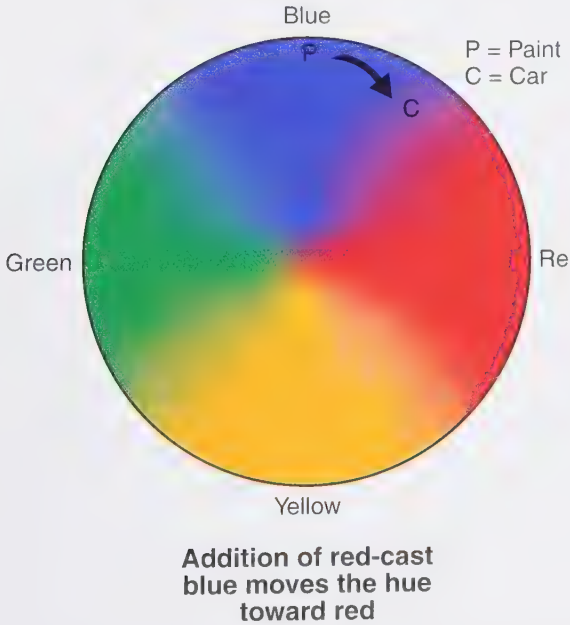


Figure 29-26. *To alter a hue, plot the refinish color and the vehicle color. In this example, adding a blue tint with a red cast will move the paint in the desired direction. (PPG)*

The value of a metallic color is adjusted by adding metallic flakes. Fine metallic flakes are gray and will darken a metallic color. Coarse flakes are relatively bright and will lighten a metallic color. Search the formula for the sizes of metallic flakes used. Add a measured amount of the fine metallic to darken the color. Add a measured amount of the coarse metallic flakes to lighten the color. Black can be added to darken silver metallic paint.

To reduce chroma in a solid color, the addition of black and white will make a solid color grayer. Adding equal parts of black and white adds neutral gray to the color, moving the color toward the center post on the color wheel. To reduce chroma in a metallic color, add metallic flakes. To increase the chroma of solids or metallics, add more of the primary tint. The primary tint is the tint used in the greatest amount. Adding more of this tint will increase chroma, making the color more intense.

On a metallic color, flop is the comparison between the face and both types of pitch. To lighten the pitch without changing the face, add white mica. To lighten the pitch and darken the face of a light metallic, such as silver, add white. Some paint manufacturers include a flop adjuster in the paint formula. Flop adjuster is intended to properly orient the metallic flakes. Even if flop adjuster is not in the formula, it can be added to lighten the pitch without changing the face. First, color correct the face. This usually involves adding selected metallics to lighten or darken the face. Once the face is correct, make adjustments to the pitch.

Subtractive Tinting

Subtractive tinting takes place at the mixing scale. If a test panel shows that a refinish paint's hue, value, or chroma is off, the painter looks at the formula and decides which aspect of the paint is off by the greatest amount. By looking at a tinting chart, the painter can determine which tint or tints should be left out of the formula when the paint is mixed. For example, if a blue paint is too red, a red tint or blue tint with a red cast can be left out. If a metallic color is too dark, the fine metallic can be left out.

When performing subtractive tinting, two mixing cans are placed on the scale, as shown in **Figure 29-28**, and the scale is zeroed. Tints are added to one can, except for the tint or tints that are to be left out. The left out tint or tints are added to the second can. In this way, the formula weights can be followed. Once the subtractive color is mixed, it can be used to make a test panel. If the test panel is off, measured amounts of the left-out tint or tints can be added to the color as needed.

If the pitch of a metallic color is too light, the paint can be darkened by remixing the color and leaving out the flop adjuster. If there is no flop adjuster in the formula, try subtracting white. This may dramatically change the color and darken the pitch.

DMC Base Code	Mass Tone	White Letdown	General Usage
900 Strong White	⬜		Used in whites and pastels when bulk of formula is white.
905 Lemon Chrome Yellow	🟨	🟨	Used where only a small amount of white is needed. Lightens flop in metallics.
906 Medium Chrome Yellow	🟧	🟨	Used in substantial amounts to give bright yellow hue. Not used in metallics.
907 Yellow Orange Moly Orange	🟥	🟥	Used as yellowish-orange tint in solids only.
909 Red Shade Moly Orange	🟥	🟥	Used as a reddish-orange tint in solids only.
917 Scarlet Red	🟥	🟥	Used in bright red solid colors.
918 Lead-free Red Shade Organic Yellow	🟧	🟧	Lead-free red shade yellow. Used in solid colors only.
919 Lead-free Inorganic Yellow	🟨	🟨	Lead-free green shade yellow. Used in solid colors only.
939 Lead-free Organic Orange	🟥	🟧	Lead-free orange. Used in solid colors only.

Figure 29-27. *Solid color tints are so concentrated that their cast or undertone is difficult to evaluate without a letdown. White letdown is used to show the effect of a tint. (PPG)*

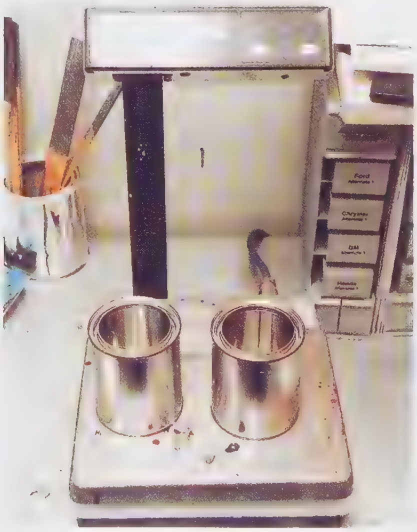


Figure 29-28. *Subtractive tinting takes place at the mixing scale. Paint will be mixed in the can on the left. The can on the right is for the subtractive tints.*

Tricoats

In a tricoat, there are two colors to match—the base and the pearl. The base color is matched by locating an area on the vehicle that has only basecoat showing, with no pearl or clearcoat over it. The base color on the letdown panel is compared to the exposed basecoat on the vehicle. If there is a difference, the refinish paint can be tinted as explained in the previous section.

Once the basecoat matches, the painter must decide how many coats of pearl or midcoat are needed to match. This is accomplished by comparing the letdown panel to the vehicle. The number of coats on the letdown panel that matches best is the number of coats that should be applied to the vehicle. See **Figure 29-29**.

At least one paint manufacturer has a way to mix paint if it happens that the correct match is somewhere in between coats on the letdown panel. By adding a 1:1 ratio of non-tinted base, the painter can create a half-coat of a pearl coat.

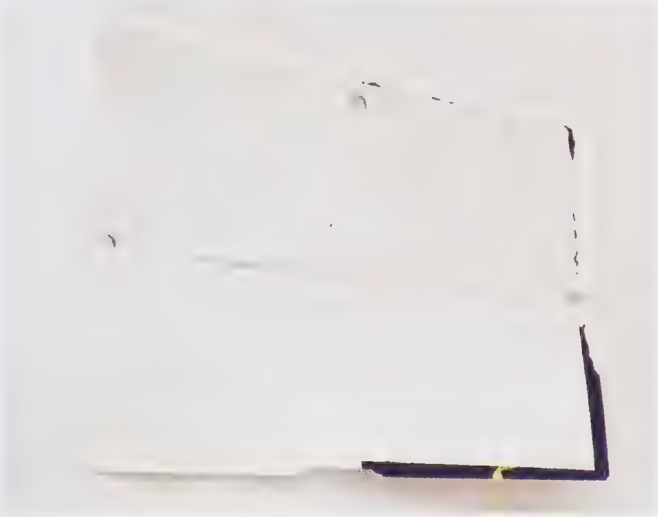


Figure 29-29. *Once the basecoat matches, the painter must decide how many coats of pearl or midcoat are needed. This tricoat letdown panel is compared to the hood of a vehicle.*

Summary

- The light source a color is viewed under determines the appearance of the color. Therefore, color should be evaluated in natural light rather than artificial light.
- The color of an object is determined by the wavelengths of the light reflected by the object.
- Red, orange, yellow, green, blue, and violet are the six visible hues in the spectrum.
- Colors can be viewed either straight on or from an angle.
- Even when paint code numbers match, the refinish paint often does not match the paint color.
- Hue is the name of the color.
- Value is the lightness or darkness or a color.
- Chroma is the intensity or brilliance of a hue.
- The three qualities of color are visually displayed in a color tree.
- Use the hue portion of the color tree, which is called the color wheel, when describing color differences.
- A comparison panel is used to check for color match.
- A letdown panel is created to color match a tricoat.
- Locating two different colors on the color tree will show the painter exactly how the colors are different. This is called plotting a color.
- A spectrophotometer is an electronic device that determines the color of a vehicle by measuring light intensity reflected from the sample.
- Color can be adjusted by tinting.

Review Questions

Please do not write in this textbook. Place your answers on a separate sheet of paper.

1. The difference between colors should be evaluated in ______ light rather than artificial light.
2. A color will always look the same under fluorescent light and under sunlight. True or False?
3. Visible light contains all the colors: red, green, blue, orange, yellow, violet. True or False?
4. Black pigment ______ all light wavelengths, while white pigment ______ all white wavelengths.
5. The color of an object is determined by the wavelengths of light reflected by the object. If that is so, the paint on a green vehicle absorbs violet, blue, yellow, orange, and red wavelengths, but it reflects the green wavelength. True or False?
6. List the three aspects of pitch.
7. A metallic color is more intense (chroma) than a solid color. True or False?
8. The orientation of metallic flakes determines the ______ or ______ of a color.
9. Which type of automotive paint has a pearl midcoat?
10. The way we see color is entirely dependent on the light source it is viewed under. True or False?
11. Men are more likely to be colorblind than women. True or False?
12. The primary hues are red, yellow, and blue. Automotive refinishers use a fourth hue. What is it?
13. The color of a paint is also known as ______.
14. A high value hue is dark. True or False?
15. Intensity, brilliance, saturation, dullness, or vividness, clean/dirty, can all be used to describe this quality of color.
16. Adding metallic to a color will do what to chroma?
17. A red can be described as too green. True or False?
18. The subtle presence of an adjacent hue in a color is called ______.
19. Two vehicles with the same paint code may have colors that are slightly different. True or False?
20. Explain how to make a letdown panel.
21. What is a spectrophotometer?
22. Spraying a metallic paint wet will make the color look ______.
23. Explain how to do subtractive tinting.

ASE-Type Questions

1. All of the following colors may be described as too green EXCEPT:
   (A) brown.
   (B) maroon.
   (C) aqua.
   (D) gold.
2. A letdown panel is to be made. Technician A wants to use basecoat and clearcoat only. Technician B wants to spray the basecoat and then spray the entire panel with pearl coat. Who is right?
   (A) A only.
   (B) B only.
   (C) Both A and B.
   (D) Neither A nor B.
3. Technician A says that subtractive tinting means to mix a color but leave out one or more tints. Technician B says that subtractive tinting requires tints to be added to the mixed paint. Who is right?
   (A) A only.
   (B) B only.
   (C) Both A and B.
   (D) Neither A nor B.
4. The hue of a red is too yellow. Which of the following should be added?
   (A) Black.
   (B) White.
   (C) Green.
   (D) Blue.
5. Technician A says that finer metallic flakes are darker than coarse metallic flakes. Technician B says that metallic flakes act as mirrors. Who is right?
   (A) A only.
   (B) B only.
   (C) Both A and B.
   (D) Neither A nor B.
6. Which of the following can be added to a red color to increase the chroma?
   (A) Red.
   (B) Black.
   (C) White.
   (D) Green.
7. The value of a metallic color is adjusted by adding ______.
   (A) metallic
   (B) green
   (C) red
   (D) blue
8. The pitch of a metallic color is too light. The face is okay. Technician A wants to add white mica. Technician B wants to add flop adjuster. Who is right?
   (A) A only.
   (B) B only.
   (C) Both A and B.
   (D) Neither A nor B.
9. Which of the following light sources is best for viewing colors?
   (A) Fluorescent.
   (B) Incandescent.
   (C) Sunlight.
   (D) Mercury vapor.
10. A green is too yellow. What tint should be added?
    (A) Red.
    (B) Blue.
    (C) Green.
    (D) Yellow.
11. Which of the following terms means that a metallic color changes depending on the viewing angle?
    (A) Value.
    (B) Hue.
    (C) Metamerism.
    (D) Flop.
12. All of the following will lighten a metallic paint EXCEPT:
    (A) faster spray gun movement.
    (B) closer spray gun distance.
    (C) wider fan.
    (D) less material.
13. Technician A says that value is the lightness or darkness of a color. Technician B says that value is adjusted by adding the primary tint. Who is right?
    (A) A only.
    (B) B only.
    (C) Both A and B.
    (D) Neither A nor B.
14. The intensity of a color is called ______.
    (A) hue
    (B) value
    (C) chroma
    (D) metamerism
15. Technician A says that a spectrophotometer assigns a number value to each dimension of color. Technician B says that a spectrophotometer is capable of making a paint formula. Who is right?
    (A) A only.
    (B) B only.
    (C) Both A and B.
    (D) Neither A nor B.

Chapter 30

Paint Application

Objectives

After studying this chapter, you will be able to:

- Understand the different levels of surface preparation.
- Recognize sources of contamination.
- Understand how to spray single-stage paint.
- Understand how to spray basecoat/clearcoat paint.
- Understand how to spray tricoat paint.
- Explain the term hiding.
- Understand how to make a blend.
- Understand how to make a melt.
- Recognize and know how to correct common refinish problems.

Technical Terms

back blend
baking
blistering
blushing
complete paint job
coverage chart
dry spray
dust-free time
front blend
halo effect
let-down panel
lifting
make up air
mapping
melt
mist coat
nib sanding
overall paint job
panel painting
run
sand scratch swelling
solvent pop
tack coat
tiger stripes
time window
two-tone finish
water spots

Introduction

Properly applied paint is durable, providing maximum protection from the environment. The paint is also the first thing a customer sees when looking at a repaired vehicle. Poor paint application will make the entire repair look bad, no matter how good the body work.

This chapter explains how to paint a vehicle. It begins with a discussion of repair planning and contamination prevention. The various ways to apply single-stage, basecoat/clearcoat, and tricoat paint are detailed. Next, basic strategies for blending within a panel and blending multiple panels are presented and procedures for baking the newly applied finish are discussed. The chapter concludes with causes and solutions to common refinish problems.

Planning the Repair

Before starting the refinishing process, the painter should plan the repair, as there are many decisions to be made. For example, the painter must decide whether the panels adjacent to the repair will be blended. Another decision is whether or not a panel will be melted. Some shops choose not to make a melt. The painter must also determine how much surface preparation should be done. One factor in deciding on the level of surface preparation is how much the shop will be paid for this labor-intensive process. *Chapter 28, Surface Preparation*, explained three standards for vehicle surface preparation. Briefly, in Level 1 surface preparation, most obstructions are not removed from the panels to be painted. Overreduced clearcoat is used to melt the edge of a repair area. Obstructions are removed in Level 2 surface preparation, while Level 3 does not allow 2-step painting. Level 1 requires the least amount of labor, while Level 3 requires the most labor and is also the most expensive option. The strategy chosen for refinishing will determine the cost, appearance, and durability of the repaint. See Chapter 28 for an in-depth treatment of this topic.

Contamination Prevention

Dirt, dust, sand, and lint are just a few of the contaminants present in the shop environment. They are easily sent airborne by compressed air or powerful spray booth fans, and always seem to land in wet paint. These particles embed themselves into the paint film and are visible when the paint dries. Color sanding and buffing will remove most contamination, but it is far better to prevent contamination from occurring in the first place. The most common sources of contamination are discussed in the following paragraphs.

The vehicle itself is the greatest source of paint contamination. The air discharged from the spray gun will dislodge contaminants from the vehicle, causing them to land in the wet paint. This can be prevented by thoroughly cleaning the vehicle before painting. Pressure wash the underside of the vehicle. See **Figure 30-1**.

Sludge from wet sanding should be rinsed off. Recessed areas, such as cowl vents, door openings, and roof drip rails can hide and hold dirt. To remove this potential contamination, blow off the vehicle with compressed air outside the spray booth before masking. After the vehicle has been moved into the spray booth, it should be blown off again as shown in **Figure 30-2**. This final step should be done with the spray booth fans running. Do not simply blow off the portion of the vehicle that will be painted. Instead, blow off the *entire vehicle*, paying special attention to all crevices, panel joints, and any other location where contamination can hide. After blowing off the vehicle, wipe down the spray area with a tack rag. The tack rag is cheesecloth coated with a sticky resin that is designed to remove any contamination still clinging to the surface. **Figure 30-3** shows how to use a tack rag. Unfold the entire tack rag and gently wipe it over the surface. Be certain to wipe all panel surfaces that will be sprayed.

Some painters attach a grounding wire, a chain, or jumper cables from the vehicle's frame or body to a metal portion of the spray booth or floor. This prevents the buildup of static electricity. Dirt or lint floating in the spray booth air may have a positive or negative charge.

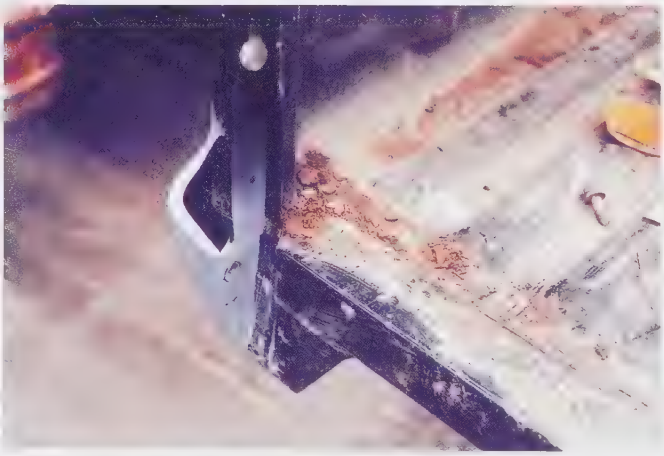


Figure 30-1. *This mud must be cleaned out before painting. Power wash the inside and underside of the truck.*

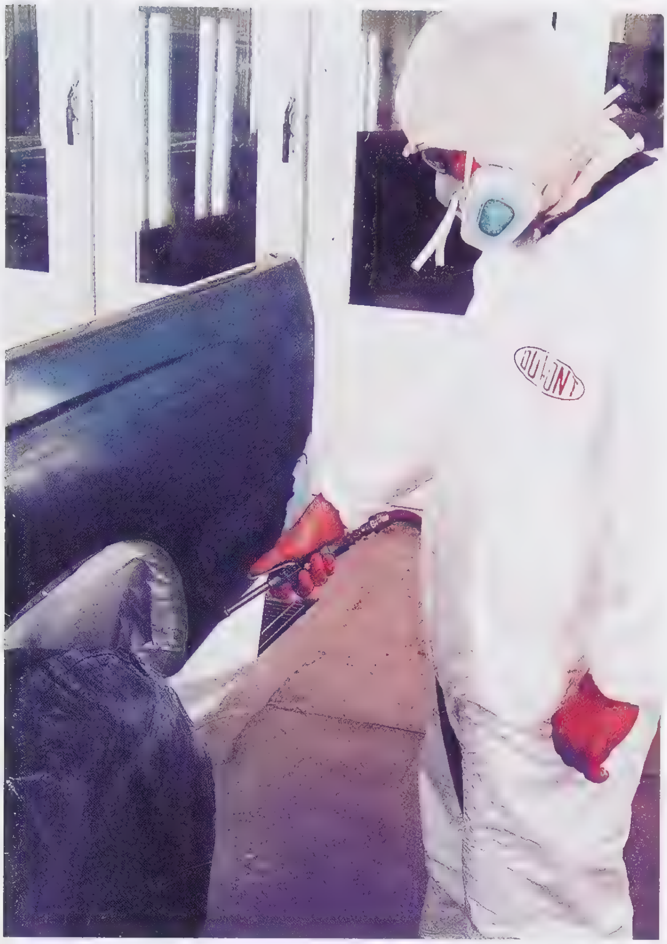


Figure 30-2. *Even if you are just painting a single panel, the entire vehicle should be blown off with the spray booth exhaust fans running.*

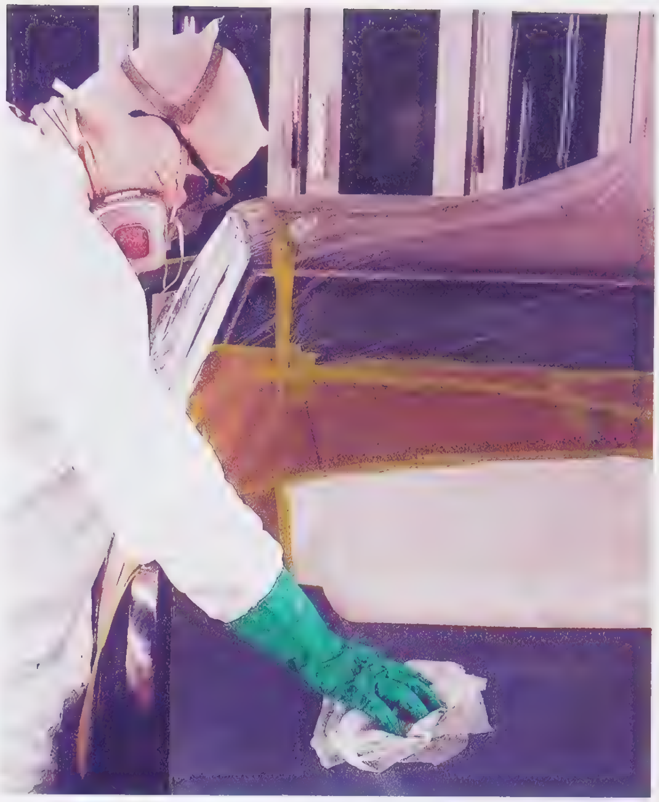


Figure 30-3. *Unfold the tack rag as shown. Gently wipe the surface. Tacking off is the last thing you do before painting.*

The static electrical charge on the vehicle may attract the charged lint or dirt to the wet paint because opposite charges attract. Neutralizing this electrical charge by grounding the vehicle is always a good idea.

The painter is another potential source of contamination. A collision repair shop is a dirty, dusty environment. It is not difficult to imagine a painter's clothing coated with a variety of contaminants. To minimize the possibility of importing contaminants into the spray booth, the painter should wear a paint suit, **Figure 30-4**. A clean paint suit will prevent contaminants from the painter's clothes from dislodging and landing in the wet paint. Paint suits can be disposable—used once or twice—or washable—used 50–100 times. The paint suit should be kept in a clean bag or locker when not being used. The painter should put the paint suit on just before entering the spray booth and take it off immediately after leaving the booth. A hat or spray sock is used to cover the painter's head. See **Figure 30-5**. Hair, sweat, and dandruff are potential contaminants from the head.

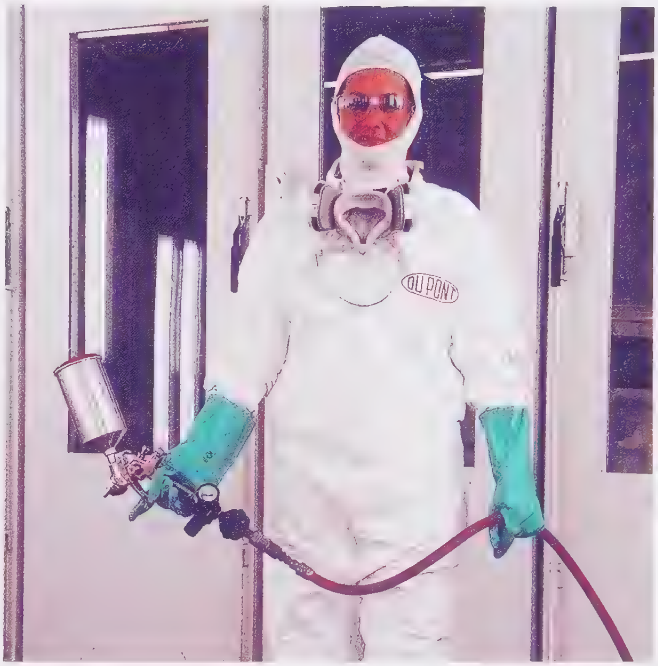


Figure 30-4. *General Motors conducted tests and determined that most of the dirt in their paint jobs came from the painters' clothing. A clean spray suit will prevent the contamination of wet paint.*

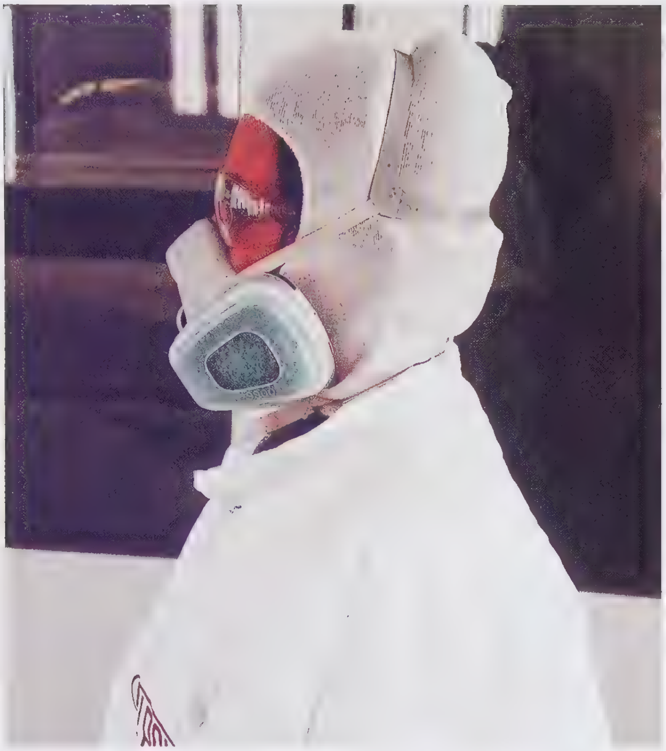


Figure 30-5. *A spray sock keeps hair out of the paint. Wash these regularly and store in a sealed plastic bag when not in use.*

As with the paint suit, the spray sock or hat should be kept clean. If gloves are worn when painting, they should also be clean. In fact, anything the painter wears must be clean, including the respirator.

The spray gun can also be a source of contamination. This contamination can come from either inside or outside the spray gun. Internal contamination occurs when bits of dried paint inside the gun break loose and are sprayed out along with the fresh paint. Dried paint can also be found on the outside of the spray gun—especially on the paint cup. **Figure 30-6** shows a spray gun with external contamination. The dried paint can fall from the outside of the gun and land in wet paint. To prevent spray gun contamination, thoroughly clean the spray gun after each use. Simply running thinner through a spray gun will not always remove internal contamination. Often a brush must be pushed into the paint passages to loosen and remove solidified paint residue.

Some spray guns have a filter in the cup. Spraying metallic paint can clog the filter with aluminum flakes. After spraying, remove the filter from the spray gun and soak the filter in lacquer thinner or reducer. Then rinse the filter under a stream of thinner. Do not use a filter if it is partially clogged. A clogged or partially clogged filter will not allow enough paint to flow through the spray gun.

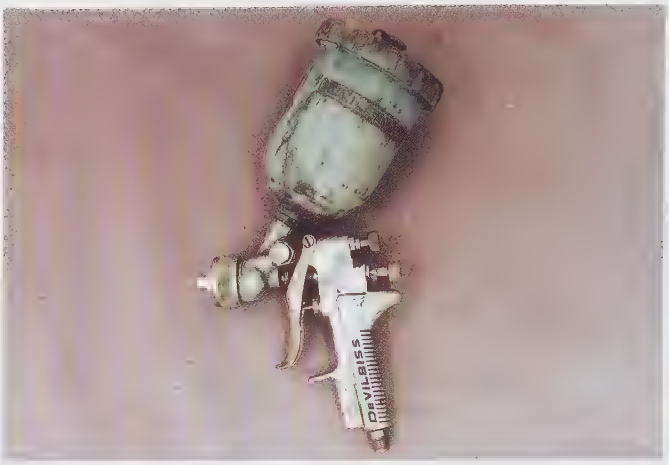


Figure 30-6. *Pieces of dried paint falling off this dirty spray gun can contaminate paint. Keep your equipment spotless for best results.*

The air hose will have overspray on it, and it may pick up dirt from the spray booth floor. Therefore, the hose should be wiped with a tack rag before painting is started. Use a separate tack rag to wipe off the hose.

Folds in masking paper will trap and hide dirt and other contaminants such as dried overspray. These contaminants can be blown into the wet paint by air from the spray gun. Folds should always be taped over. See **Figure 30-7**. If the masking paper is covered with dried overspray from previous coats, the paper can be wiped with a tack rag before the next coat is applied.

The spray booth intake filters should be clean and fit tight. If necessary, the filters can be blown out while the fan is running. This will remove contamination from the filters. If the spray booth has an exhaust fan only,

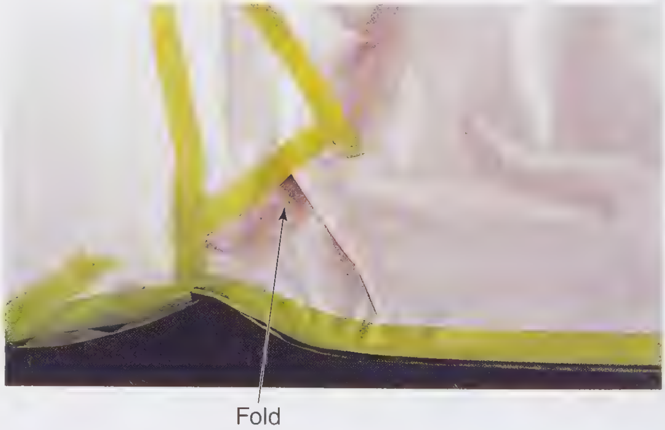


Figure 30-7. *This fold in the masking paper will trap contaminants such as dry overspray and sanding dust. Then, compressed air from the spray gun blows it into the wet paint. Tape over all folds!*

the booth should be airtight so all air drawn into the booth is filtered. If the booth has positive pressure exhaust and intake fans, air is pushed out of the booth rather than drawn in, and contaminants are not drawn into the booth.

The spray booth walls and floor should be cleaned daily in a shop that runs three or more vehicles through the booth in one day. A rinseable booth coating can be applied to the walls. Some shops hose down the spray booth floor so the floor is wet while the vehicle is being painted. The water will trap and hold contaminants that fall to the floor, but the air hoses will get wet, so the painter must be careful not to let water from the hoses drip onto the paint.

The paint itself can be a source of contamination. If a conventional spray gun paint cup is used, the paint is reduced in a separate container and strained through a filter as it is poured into the paint cup. Disposable paper filters may shed fibers into the paint as it is poured through the filter. If a disposable paint cup is used, the paint is reduced in the cup. The disposable paint cup has a built-in filter. The filter will remove clumps of metallic flakes or contamination that may be in the paint. The fibers are contaminants. A reusable nylon or metal mesh filter will not shed fibers.

In summary, anything in the spray booth can be a source of contamination, even lint from clean wiping cloths. Clean everything that goes into the booth. Cleanliness should be a priority during every phase of the refinishing sequence. This is especially true when painting.

WORKING GREEN

By adopting best practices recommended by the U.S. EPA's Collision Repair Campaign, which include installing and maintaining control equipment and using safer paints and solvents, toxic exposures are expected to be reduced by 90%.

Applying Paint

This section will explain how to apply paint. There are three types of paint used in automotive refinishing: single-stage, basecoat/clearcoat, and tricoat. Most paint sprayed in today's body shops is basecoat/clearcoat. However, a technician may be called on to spray the other types of paint.

Applying Single-Stage Paint

Single-stage paint is color only. The two types of single-stage paint commonly used on passenger cars and light trucks are acrylic enamel and urethane enamel. These paints are formulated to match OEM colors. Synthetic enamel or polyurethane enamel single-stage paints can also be used for vehicle refinishing. However, these paints are not available in OEM colors. The following sections outline single-stage paint application when performing spot repairs, painting an entire panel, or refinishing a complete vehicle. Two-tone painting will also be discussed.

Spot Painting

In spot painting, only a portion of the panel is painted. It is easier to spot paint a solid color than a metallic color. This is because the pattern of aluminum flake dispersion in a metallic color must match the surrounding paint for an invisible repair.

If surfacer is applied to the panel, the spot painting should extend approximately 6" beyond the edge of the surfacer. Adjust the spray gun so the pattern is not larger than the area covered by the surfacer. If the repair area is taller than 9", adjust and set the spray gun fan to maximum coverage. Sand the surfacer and a 2" area around the repair with 600-grit sandpaper. Apply the first coat of paint to cover the repair and allow it enough time to flash. Tack off the repair area, especially the dry overspray at the edge of the first coat. Apply the second coat beyond the dry edge of the first coat. Again, allow this coat to flash and tack it off. Apply the third coat, extending it beyond the edge of the second coat.

Spraying paint to cover the surfacer will put dry paint overspray at the edge of the spray area. This is unavoidable because whenever a paint stroke is stopped on a panel, the edge of the stroke will have overspray. A ***melt*** will hide overspray by dissolving it. In a single-stage melt, overreduced paint is sprayed on the dry overspray to flood the area. This dissolves the dry overspray and makes it less noticeable. Prepare the melt area beyond the sanded portion of the panel by rubbing with compound. The rubbing compound will remove any oxidized paint and create a smooth surface.

To perform the melt, remove the remaining paint from the spray gun. Overreduce a small amount of the remaining paint with an equal amount of reducer. Adjust the spray gun to set a small fan of about 3". Adjust the material control to fill the fan with paint. Set the air pressure at 20 psi for conventional spray guns and 5 psi or less for HVLP spray guns. Spray the dry area at the edge of the repair with the overreduced paint. This paint will easily run, so be very careful. At least two applications of overreduced paint are required to melt the dry edge. See **Figure 30-8**.

NOTE

The melt should be made as soon as possible after the last coat of paint is applied.

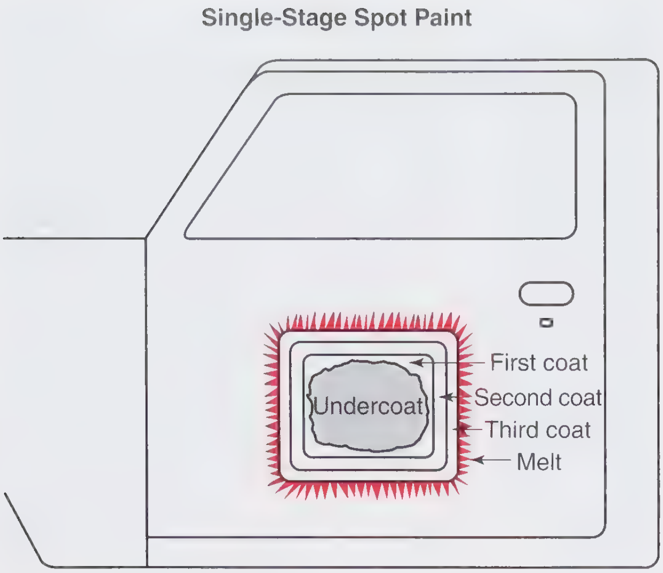


Figure 30-8. *In single-stage spot painting, each coat of paint is stepped out from the previous coat.*

Panel Painting

Panel painting means that an entire panel is refinished. See **Figure 30-9**. To refinish a panel, remove the obstructions to the level required by shop policy. Clean, sand, and mask the surface. Mix paint, and then load and adjust the spray gun. Set the spray gun at the recommended air pressure. Some paint manufacturers recommend the first coat to be a tack coat. A ***tack coat*** is a dry, slightly rough coat. The rough surface of the tack coat allows the wet coats that follow to adhere without running. Wet coats will give a better appearance and gloss than drier coats. The tack coat can be applied dry by turning the fluid control knob clockwise. This reduces the amount of paint that flows out of the gun's air cap. Faster spray gun travel speed or greater distance will also cut back the amount of paint applied. Of these three methods, reducing the amount of paint delivered to the air cap is preferred. Spray on the tack coat, or first coat, as recommended.

Figure 30-9. *When panel painting, the entire panel is sprayed. Observe the paint manufacturer's recommended flash time to avoid runs and solvent pop.*

Allow the wet paint to flash. Flash time is the number of minutes it takes for the solvents in freshly applied paint to evaporate, leaving the paint dry enough to touch. If there is good airflow in a downdraft or crossdraft spray booth, flash time will be reduced. Not allowing adequate flash time will lead to problems. Problems include runs, because the first coat of paint is still too wet when the second coat is applied, and ***solvent pop***, which is caused by trapped solvent.

Tack off the paint after the first coat has flashed. The second coat is sprayed medium-wet. The third coat, also medium-wet, is sprayed after the second coat has flashed. The second coat will be too sticky or wet to tack off before the application of the third coat. The idea is that the second and third coats are applied wet enough to flow out to make a smooth surface. The third coat, the last coat, is the coat that will be seen.

When metallic paint is sprayed, the metallic flakes may not be dispersed uniformly in the paint film. The clumping of the metallic flakes is called mottling.

Tiger stripes are dark bands in a light metallic color. Tiger stripes are the result of uneven paint application, which is caused by an improperly adjusted spray gun (air pressure set too high), heeling (tilting the spray gun so the fan is not perpendicular to the panel), or a dirty air cap (dried paint blocking the fluid tip so one part of the fan has more paint than the other). The area with the dark band was applied slightly wetter than the surrounding paint. If the air cap is clean and the spray gun is properly set up, you can eliminate mottling or tiger stripes by applying a mist coat. A ***mist coat*** spreads the metallic flakes evenly in the paint film. A mist coat is only needed after the final color coat. After the last coat of color is applied, the mist coat will properly position the metallic. The mist coat is sprayed with no flash time, so it can settle and melt into the wet paint. A mist coat is sprayed at twice the normal distance, **Figure 30-10**. When light-colored metallics, such as silver or gold, are applied on horizontal surfaces, a diagonal spray pattern can be used on the mist coat. This will help break up the tiger stripes. See **Figure 30-11**. Another tactic is to lower viscosity by adding 10% more reducer, but keeping the air pressure setting the same. Thinner paint atomizes better, reduces the likelihood of clumping, and makes for a more uniform metallic flake distribution.

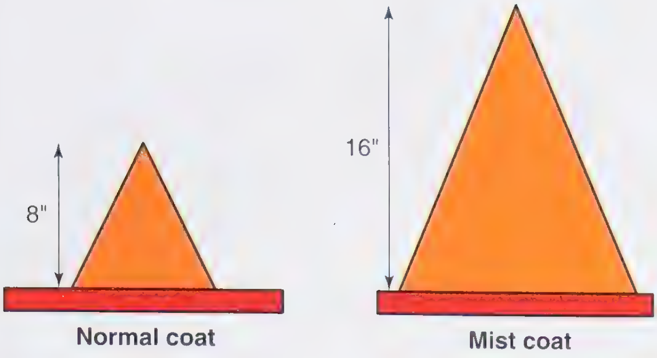


Figure 30-10. *A mist coat is made by holding the spray gun at twice the normal distance from the panel. A mist coat is sprayed immediately after the last coat so it can melt into the wet paint and evenly disperse the metallic flakes.*

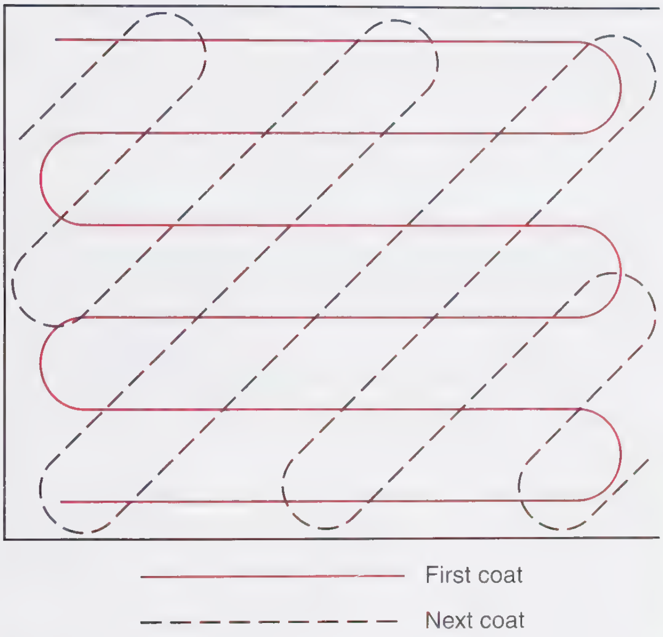


Figure 30-11. *This diagram shows one way to minimize mottling and tiger stripes. The first coat is parallel to the long dimension of the panel. The next coat is applied diagonal to the first coat.*

Complete Paint Job

A ***complete paint job***, also called an ***overall paint job***, involves spraying the entire vehicle. In a complete paint job, the main concern is to keep overspray off surfaces that have already been painted. This is difficult for a single painter. Therefore, it is better to have two painters on an overall paint job.

Pay attention to the direction of airflow in the spray booth and work with it—not against it. In a crossdraft booth, start at the end of the vehicle near the air intake and work toward the other end of the vehicle near the exhaust. In a downdraft booth, spray from top to bottom.

Always paint the hood, the roof, and the deck lid as separate panels. Stagger the overlap areas if the vehicle's sides are painted in sections. See **Figure 30-12**. Some painters prefer to walk the sides of the vehicle rather than paint the fenders, doors, and quarter panels in sections.

If recommended, apply a tack coat first and allow it to flash. Then tack off the paint and the masking paper. Apply the second coat medium-wet. Allow the second coat to flash off. Spray the third coat medium-wet. If a mist coat is needed, apply it immediately after the third coat.

Two-Tone Finishes

If a ***two-tone finish*** is required, the painting process should be viewed as two separate operations. There are two ways to apply a two-tone finish. Begin the first method by spraying the first color and allowing it to dry. Before you mask off the first color, make sure the paint is completely dry. Masking tape can leave a visible line in fresh paint, even if the paint appears to be cured. Masking tape applied to fresh paint will make an indentation in the paint and may also remove paint as the tape is removed. Use only 1/4" fine-line masking tape, not regular masking tape. Fine-line tape makes a sharp edge. Reduce the stickiness of the fine-line tape by dragging the tape over your pant leg. This takes off some of the tape adhesive. The tape is less sticky and less likely to make an indentation or remove paint. Apply the tape with light pressure; do not press the tape in place.

WORKING SMART

Some painters "kill" the masking tape before applying it by dragging the tape across a pant leg. This takes some of the stickiness out of the tape, making the tape less likely to pull up the first basecoat.

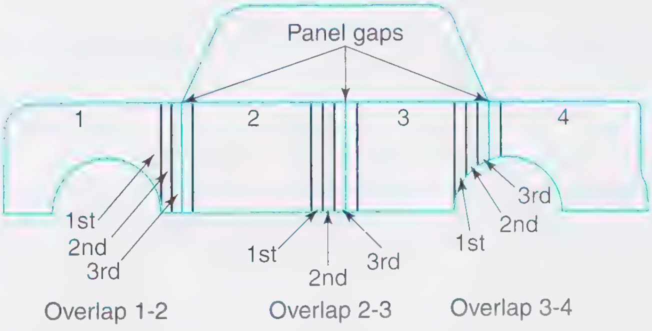


Figure 30-12. *Staggering overlaps prevents dark bands at the end of the strokes. Notice how the pattern is designed for the last coat to overlap at the panel joints.*

If the first color was not sprayed to cover the entire panel, there will be dry overspray where the second color will be applied. Remove this overspray by sanding the area smooth with 600-grit wet sandpaper. Be sure to sand the area adjacent to the masking tape. The masking tape defines the border. Remove the masking tape and clean off the sanding sludge.

Retape the border between the colors with 1/4" fine-line masking tape. If the entire panel was repainted, and no dry overspray is present, check the paint manufacturer's requirements to see the time window for two-toning. The ***time window*** is the number of hours that the fresh paint will accept additional coats without requiring sanding the fresh paint to promote adhesion of the additional coats. If too much time elapses between colors, the first color must be sanded to accept the second color. If too much time has passed, apply 1/4" fine-line masking tape to form the border and mask off the area. Scuff-sand the area that will be sprayed with the second color. Within the time window, the border can be made with 1/4" fine-line tape. The fine-line masking tape must form a barrier that the second color cannot creep under. Apply regular masking tape and paper to the fine-line tape. About 1/8" of the fine-line tape should be visible.

In the second method of two-tone painting, the border is masked off before the first color is applied. Again 1/4" fine-line masking tape is used. See **Figure 30-13**. The first color is applied and the masking is removed. The first color is then masked by carefully taping on the border with killed 1/4" fine-line masking tape. To prevent a visible difference in the height of the two colors, it is essential that the tape be applied exactly at the edge of the first color. Masking tape and paper are applied to protect the first color. Make sure the first color has cured completely before masking. The second color is applied and the masking is removed.

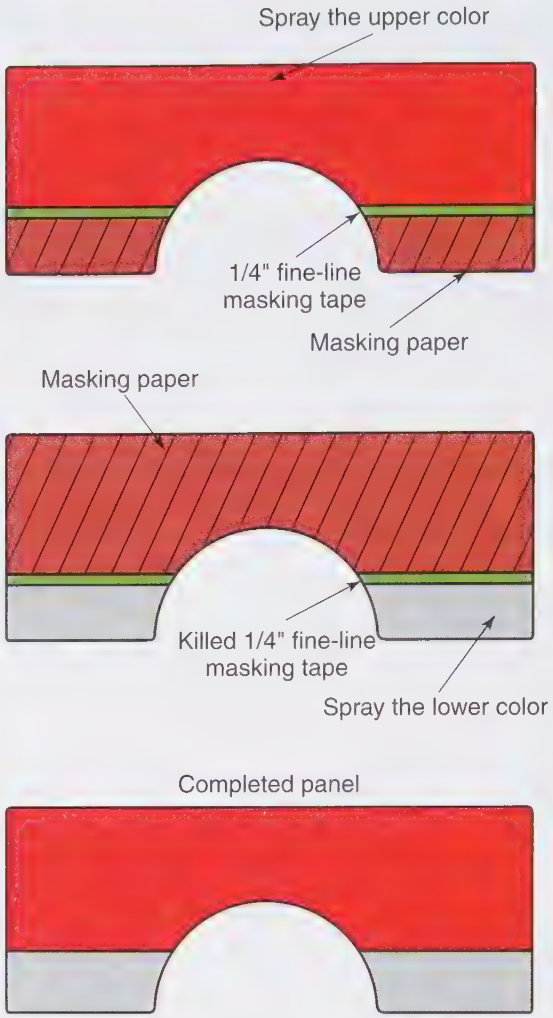


Figure 30-13. *Two-tone painting should be viewed as two separate operations. First, masking is used to cover the lower panel. Then, after drying, the masking is reversed.*

Applying Basecoat/Clearcoat Paint

Most body shops spray vehicles with urethane basecoat/clearcoat finishes. The following sections outline basecoat/clearcoat paint application when performing spot repairs, painting an entire panel, or refinishing a complete vehicle. Two-tone painting is also covered.

Panel Painting

As previously discussed, panel painting involves painting an entire panel. After the panel is prepped and tacked, the first coat of basecoat is sprayed. The basecoat will look shiny immediately after it is applied, but it will become dull as it dries. Once the first coat of basecoat has flashed, it should be wiped down with a tack rag. The second coat of basecoat can then be applied over the first. Most solvent basecoats cover in three coats, waterborne basecoats may cover in two coats. Always allow solvent basecoats to flash in between coats.

Basecoats are sprayed to hiding. This means that additional coats of the base are applied until the undercoat is no longer visible through the basecoat. Some basecoats are better at hiding the undercoat than others. Red, especially red pearl, and black are poor hiders, while dark blue is a good hider. Be certain the undercoat is not visible before moving on to the next step. If the spray booth lighting is not bright enough, it may be difficult to tell if the undercoat is completely covered and hiding may not yet be achieved. When an improperly painted vehicle is viewed in bright sunlight, the undercoat may become visible through the basecoat. Some shops shine a bright halogen lamp on the repair area to check for coverage before the application of clearcoat.

A ***coverage chart*** can be taped to masking paper near the spray area. Apply a coat of paint to the coverage chart every time you apply a coat of basecoat to the vehicle. Hiding is achieved when the black-and-white sections of the coverage chart are no longer visible. See **Figure 30-14**.

With some basecoats, two coats may be enough to achieve complete coverage. However, most colors cover in three coats. A poor hider may require four coats. Coverage is influenced by the color of the undercoat. If the undercoat has been tinted to match the basecoat, hiding should occur with fewer coats.

Spraying white basecoat can be challenging because it reflects so much light that it is difficult to see how effectively the paint is covering. This may lead to runs in the basecoat. To prevent this problem, apply white basecoats slightly drier than a typical basecoat. The paint can be applied drier by increasing spray gun travel speed, increasing distance, or decreasing the amount of paint mixing with the atomizing air.

Once the undercoat is covered, the basecoat should be allowed to flash before the clearcoat is applied. Check the manufacturer's recommendations for the proper flash time. Basecoat should be wiped down with a tack rag before the first coat of clear is applied. Do not sand basecoat before applying clearcoat.

Dirt in the basecoat is impossible to remove once the clearcoat is applied over it. Some painters dry nib sand the basecoat with 1000-grit sandpaper before the final coat of basecoat is applied. The intent is to remove dirt, not to sand the surface smooth. In ***nib sanding***, the sandpaper glides over the surface, leveling the high areas of dirt specks trapped in the basecoat. Buffing will often remove dirt in clearcoat, so nib sanding is not needed between coats of clearcoat.

Some painters clean the spray gun after spraying basecoat and before spraying clearcoat. Other painters empty out the spray gun cup but do not clean the gun before spraying clear, as the amount of basecoat in the spray gun is insignificant when diluted with clearcoat. Paint manufacturers recommend using separate spray guns for basecoat and clearcoat.

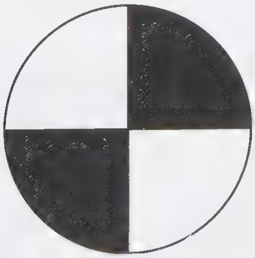


Figure 30-14. *Every time you spray a coat of base on a vehicle, you also spray a coat on the coverage chart. Basecoats are sprayed to hiding. Additional coats of base are applied to the vehicle if the black and white of the coverage chart are still visible.*

Clearcoat, when applied properly, will make the entire paint job look good. Conversely, poor clearcoat application will make the job look bad.

There are two common problems when spraying clearcoat: dry spray and orange peel. ***Dry spray*** means that not enough clearcoat is applied to wet the surface. Dry spray looks rough and dull. To avoid dry spray, carefully observe overlaps and maintain a consistent distance and travel speed. Orange peel results from poor atomization. Good atomization will break up the clearcoat into tiny droplets, which flow together to create a smooth surface after application. Poor atomization does not break the clearcoat into droplets that are small enough. The larger droplets do not flow together properly, leaving the surface somewhat bumpy. A properly adjusted spray gun will prevent orange peel.

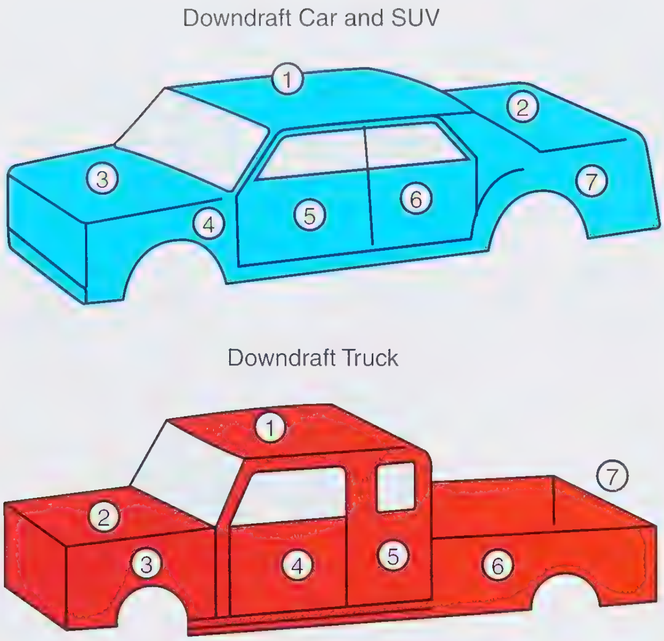
Clearcoat can be difficult to spray because it goes on clear, making it hard to determine which areas have already been painted. This is generally not a problem with the first coat of clear, because the clearcoat will brighten the dull basecoat. However, all additional coats will be difficult to see. Double coverage of an area can lead to runs. By concentrating on proper spray technique, the painter can prevent covering an area twice in one coat. Runs in the clearcoat can be removed after the clearcoat is dry. The paint manufacturer may recommend two or three coats of clear. For durability, the clearcoat film build should be at least 2 mils thick. Excessive coats of clear—four or more—serve no useful purpose and may cause problems. Do *not* tack off the surface between coats of clear, and observe the recommended flash time.

Overall Painting

An overall basecoat/clearcoat paint job is similar to an overall single-stage paint job in that the painter follows the air movement in the spray booth. In a cross-draft booth, start spraying at the end of the vehicle near the air intake and work your way toward the exhaust. In a downdraft booth, start at the top of the vehicle and work down. See **Figure 30-15**. Spray the basecoat to hiding. Stagger the overlapped areas if the sides are painted in sections.

Paint each horizontal panel as a single unit. Some of these panels, such as the hood or roof on a four-wheel drive pickup or van, may be beyond the painter's reach. To spray these large surfaces, the painter can stand on a bench. After the basecoat has been applied, the painter should wait for the manufacturer's recommended flash time to elapse before tacking and applying the clearcoat. Spray two or three coats of clear.

Never stop spraying clearcoat in the middle of a panel. Always end clearcoat spraying at the edge of a panel. For example, on a four-door vehicle, spray the clearcoat on the entire fender, ending at the gap between the fender and the door. Move to the front door.


Downdraft Car and SUV

Downdraft Truck

Figure 30-15. *For a complete paint job in a downdraft booth, start at the top of the vehicle and work down toward the exhaust. This keeps overspray from falling on already painted surfaces.*

Spray the entire door, beginning at the fender/door gap and ending at the front door/rear door gap. This puts the majority of the overspray from ending a stroke in a panel gap and not on the panel.

Clearcoat overspray will make the panel look dull. As the vehicle is sprayed, overspray from painting one panel will land on an adjacent panel. For example, spraying the roof will scatter overspray on the hood and deck lid. Plan a spraying strategy that puts overspray only on panels that will be sprayed next. Covering the clearcoat overspray with wet clearcoat will make the overspray melt and disappear.

Creating a Blend

A blend is used to hide a slight mismatch between the refinish paint and the vehicle paint. Blends are very common on basecoat/clearcoat vehicles. There are two types of blends: front blends and back blends. In a ***front blend***, the first coat of base is sprayed over the primer or the replacement part. Proper triggering is important when spraying metallic paint using an I-stroke or a J-stroke. (Refer to Chapter 27 for detailed information on stroke technique.) The painter must trigger off at the end of the stroke; then trigger on at the beginning of the next. This will keep the dry overspray at the end of the stroke to a minimum. The spray gun should not be fanned at the end of the stroke. Fanning will cause a slightly drier spray at the end of the stroke. See **Figure 30-16**. This drier spray will cause the paint color to appear lighter at the edge. This is called the ***halo effect***. Use of a J-stroke will prevent the halo effect. See **Figure 30-17** for an example of a blend within a panel.

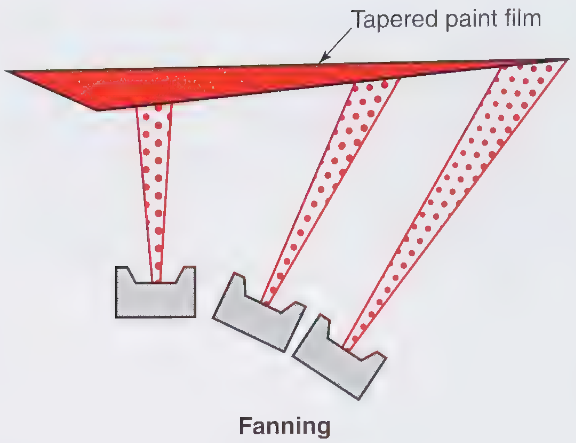
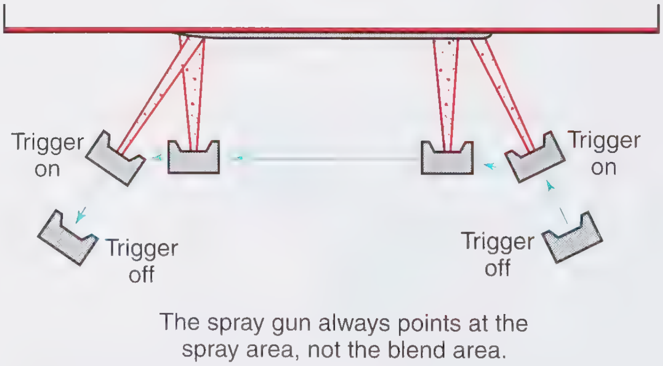


Figure 30-16. *If the spray gun is fanned, the distance between the spray gun and the panel increases at the end of the stroke. This can cause the edge of the painted area to appear light.*

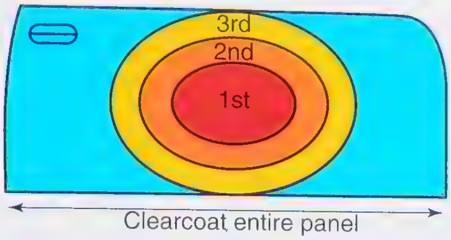
After allowing the first coat of a front blend to flash, tack off the basecoat, especially the dry edge. Then apply the second coat of base so it covers the first coat and extends out about 2" from the edge of the first coat. Allow the second coat to flash and tack off the overspray from around the edge of the second coat of base. Apply the final coat so it extends about 2" beyond the second basecoat. The blend gives a tapered edge to the paint. Triggering is very important on the last coat of base. See **Figure 30-18**.

After the final coat of basecoat has flashed, the paint area is tacked off in preparation for the clearcoat. The clearcoat can be stepped out in the same way as the basecoat. If two coats of clear are to be applied,



The spray gun always points at the spray area, not the blend area.

Figure 30-17. *The J-stroke always points the spray gun at the area that will be covered with paint, not at the blend area. This stroke is moving from right to left, the next stroke moves from left to right.*



Front Blend Basecoat

Figure 30-18. *This is a front blend. Each coat covers slightly more area than the previous coat. Triggering is very important on the final coat of base. (Sherwin Williams)*

spray the first coat over the fresh basecoat only. Then spray the second coat over the entire panel. If three coats of clear are sprayed, cover the fresh basecoat with two coats of clear and then spray the last coat over the entire panel.

In a ***back blend***, the first coat of base is sprayed over the primer or replacement part and over the entire area to be blended. A back blend is a stepping-in process. The next two coats of base are brought in about 2" each. Tacking between coats to remove overspray is important, as well as proper triggering. **Figure 30-19** shows a back blend. Clearcoat is sprayed in the same way as it is in a front blend.

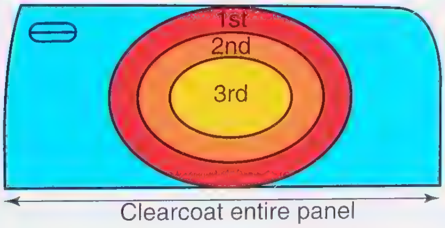
The front and back blends have been described using normally reduced basecoat, but blends can also be made using a modified basecoat. One paint manufacturer offers a basecoat blender. This basecoat diminishes the opacity of the paint. Some of these basecoat blenders require reducing while others come ready to use.

One method of using a basecoat blender is to spray normally reduced basecoat to hide the repair. Once the repair is covered, the remaining basecoat is mixed at a 1:1 ratio with reduced basecoat blender. Do not over-reduce. (Many paint manufacturers recommend a ratio of two parts reduced paint to one part blender.) Two coats of this mixture are sprayed at the edge of the repair, one coat extending further than the other. The entire panel is then clearcoated. Other methods go beyond the edge and recommend spraying basecoat blender over the entire repair area.

A two-gun method can also be used for blending. In this method, the repair area is sprayed with basecoat to hiding. Next, a spray gun loaded with basecoat blender is used to apply a coat at the edge of the basecoat. Finally, the basecoat gun is used immediately to spray over the basecoat blender. This will prevent a halo.

If possible, hide the blend. Paint on a vehicle, especially metallic paint, will look slightly different as the viewing angle changes. Any change in panel contour will slightly alter the appearance of a color. Use change in panel contour to make the color difference between the vehicle paint and the refinish paint less noticeable. In addition to panel contour, making a blend at a tape stripe, molding, or wide panel gap will help hide a blend.

One method used to blend waterborne basecoat is to make an alligator for basecoats that are lighter than neutral gray. As a reference, neutral gray is made by adding one part white to one part black. Basecoat



Back Blend Basecoat

Figure 30-19. *This is a back blend. Each coat covers slightly less area than the previous coat. Tacking between coats to remove overspray is important.*

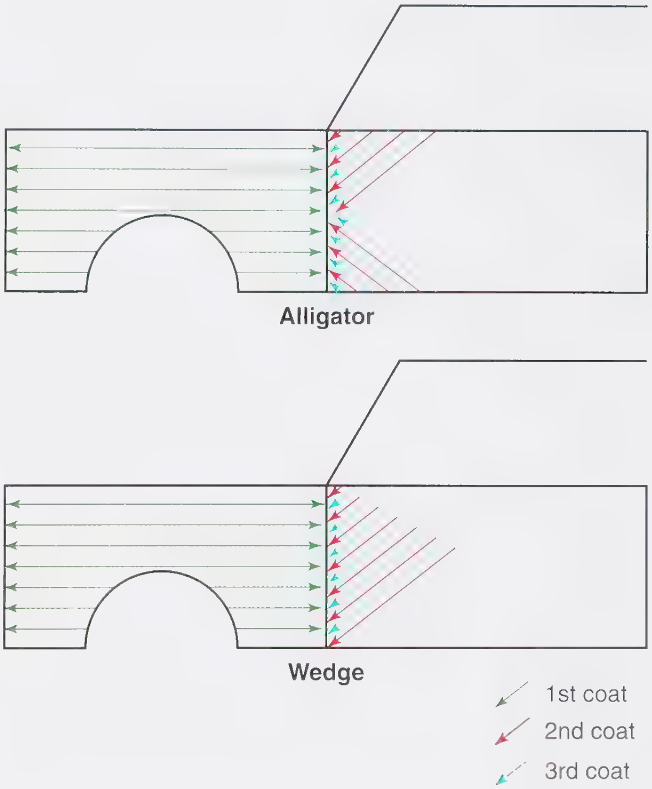


Figure 30-20. *A—The fender receives 3 coats of waterborne basecoat. The alligator is made by stepping the second and third coats, moving the spray gun towards the wet paint, and converging on the center. B—The wedge is also made by stepping the second and third coats of paint and moving the spray gun toward the wet paint in increasingly longer strokes.*

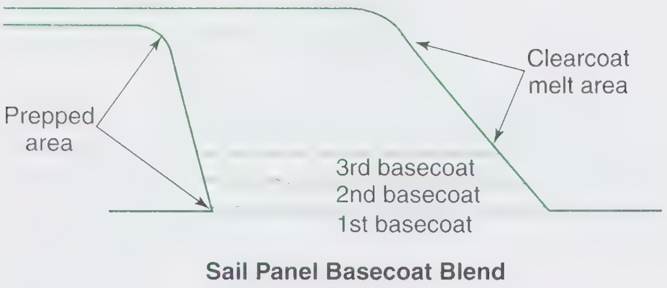


Figure 30-21. *This is a blend on a sail panel. The basecoats are tapered into the sail panel. The clearcoat is melted because there is no break between the roof and the quarter panel.*

colors that are the same as neutral gray or darker than neutral gray are blended by spraying a wedge. Both the alligator and wedge are sprayed in one direction only; always moving the spray gun toward the wet paint. A fender replacement and door blend in a downdraft booth is shown in **Figure 30-20**. If the waterborne basecoat requires three coats, the first coat is sprayed to cover the fender only. The next coat covers the fender and steps out to make half of the alligator or wedge. The final coat of waterborne basecoat covers the fender and completes the alligator or wedge. Fanning of the edge of the wedge or alligator is allowed after the last coat. The metallic in waterborne basecoat is more likely to “lay down” correctly when fanned than a solventborne basecoat.

Creating a Melt

A melt is a thin application of clearcoat used to make an invisible repair in basecoat/clearcoat paint system. This thin film of clearcoat is not durable. If the melt is on an upper surface of the vehicle, such as the hood or roof, the UV radiation exposure will eventually cause the paint to lose adhesion.

Always choose a narrow area—less than 6" wide—in which to make the melt. The most common place to make a melt is on the sail panel when a quarter panel is repaired. Because there is often no break between the roof and the quarter panel, the sail panel must be melted. Prepare the sail panel for a melt as described in *Chapter 28*. Some paint manufacturers recommend that an adhesion promoter be applied to the melt area. The basecoat is stepped as shown in **Figure 30-21**. A back blend or front blend can be used. After applying the basecoat, allow it to flash, and tack it off.

When applying the clearcoat in the melt area, a one- or two-gun method may be used. Although both methods are acceptable, the two-gun method is preferred. The two-gun method allows the painter to immediately melt the edge while the wet clearcoat is still flowing out. The one-gun method requires the painter to dilute the clear and then apply the diluted mixture to the panel. The previously applied clearcoat may have set up by the time the diluted clear is applied, and the diluted clear may run instead of melt in.

To perform the one-gun method, spray the first coat of clear to cover the basecoat only. Allow the clear to flash and tack off the overspray at the edge of the clearcoat. Next, spray the second coat of clear 1" beyond the first. If a third coat of clear is needed, step it out an additional inch. Pour out the clearcoat and add blending clear to the spray gun. If blending clear is not available, pour out most of the clearcoat from the gun and reduce the remaining clear at a 1:1 ratio with slow-dry reducer. Tack off the edge of the melt. Spray the blending clear at 20 psi in a conventional spray gun or 5 psi or less in an HVLP spray gun. Wet the melt edge. Be careful because this thin, overreduced paint will run like water. Spray two coats on the edge of the clear. Allow the first coat to dry before spraying the second coat.

The two-gun method has ready-to-spray clearcoat in one gun and blending clear in the other. Ready-to-spray clearcoat already contains the correct amount of hardener. Blending clear is sold ready-to-spray by the manufacturer and is a mixture of clearcoat and solvent. The solvent will dilute, soften, and melt the dry overspray at the edge of the clearcoat, making the repair invisible.

There are two ways to perform the two-gun melt. In the first method, a front blend, clearcoat is sprayed over the basecoat. Then the gun containing blending clear is used to wet the edge of the clearcoat. The next coat of clear is stepped out about one inch from the first. Again, the blending clear is immediately applied to the edge of the clear. If three coats of clear are applied, follow the same procedure: spray a coat of clear slightly beyond the previous coat and then spray blending clear over the edge of the clear.

The second method, a back blend, is slightly different. An 8" band of blending clear is sprayed first. Then the clearcoat is sprayed within the band, but not up to the edge of the blending clear. See **Figure 30-22**. The blending

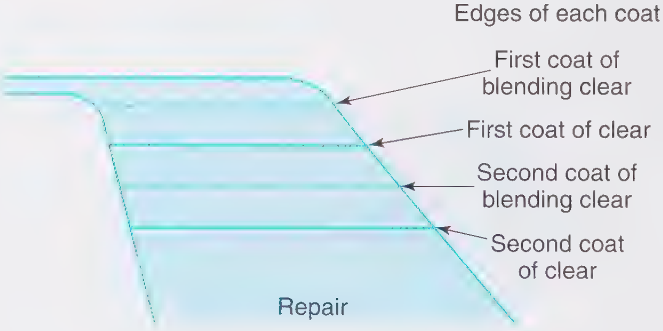


Figure 30-22. *This is the two-gun method of melting clear. In this method, the blender may be sprayed before the clearcoat or over the edge of the clearcoat. A back blend technique is shown.*

clear is sprayed out about 1" from the edge of the first coat of clear and the next coat of clear is sprayed so the edge is within the blending clear. If a third coat is needed, the same process is repeated.

Two-Tone Painting

If a two-tone paint job is required, one base color is sprayed and allowed to dry for about 30 minutes. The first base color is then masked off and the second base color is sprayed. Once the second base color is allowed to flash, the entire refinish area is clearcoated.

There are two methods of two-tone painting. The first method requires that the junction of the two base colors be laid out with fine-line tape before the first color is applied. See **Figure 30-23**.

Thirty minutes after the first basecoat is sprayed, the tape is removed and the first basecoat is masked off by masking at the junction with killed fine-line tape. Be careful. Stay exactly on the line. Any deviation will be visible as a defect in the final result.

The second method of two-tone painting is to spray the first basecoat and allow it to dry. After 30 minutes, the first basecoat is masked off. To minimize the need for sanding, the first color can be applied to the entire panel so there is no edge of overspray on the panel. If sanding of the first color is required, kill 1/4" fine-line masking tape and apply the tape exactly at the junction of the two colors. Sanding removes dry overspray in the area that will receive the second color. Sand the panel as required. Remove the masking tape and clean off the sanding sludge. Reapply killed 1/4" fine-line masking tape to the junction. The first application of tape defines the border; removing the first application of tape allows the panel to be cleaned. The second application of tape will be used to make the edge between the two colors. If no sanding is required, apply killed 1/4" fine-line masking tape to the panel to form the border between the two colors. After applying the fine-line tape, mask off the first color to protect it from overspray, and apply the second color. Remove the masking from the first color and wait the required flash time. Finally, apply clearcoat to both colors.

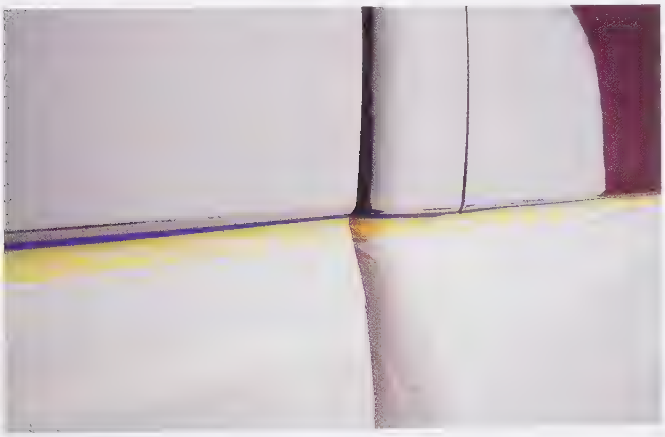


Figure 30-23. *Fine-line masking tape forms the border between the two colors. The maroon basecoat will be sprayed and the masking will be removed. After curing, the maroon will be masked off and the second color, a silver basecoat, will be sprayed. Masking is removed and both basecoats are sprayed with clearcoat.*

Applying Tricoat Paint

A tricoat is more time-consuming to spray than a basecoat/clearcoat, but except for the number of layers, the process is similar. A tricoat consists of a basecoat—usually a solid color, such as white—a midcoat, and a clearcoat. The purpose of a tricoat is to add depth or to impart a unique look. The midcoat can be a tinted base clear (translucent) or a base clear with pearl in it. The midcoat is not there to cover the basecoat color, but rather to tint the basecoat, allowing you to view the basecoat.

Color matching depends on the number of midcoats applied. A letdown panel should be sprayed before painting a tricoat vehicle. A ***letdown panel*** is a paper test card used by the painter to determine how many coats of midcoat are needed to match the existing paint.

Panel

Painting a panel with a tricoat is very simple. The panel is prepped and the basecoat is sprayed to hiding. Allow flash time between coats and tack off the panel before each additional application of basecoat. After the basecoat has flashed, the required number of midcoats is applied. After the last midcoat has flashed, the clearcoat is sprayed on.

Overall

An overall tricoat refinish is similar to basecoat/clearcoat refinish. Because so many coats are applied, dirt contamination is more likely in a tricoat refinish. The steps in a tricoat overall are summarized below:

1. Spray the basecoat to hide the primer. Observe flash times and tack off between coats.
2. Spray the desired number of midcoats. Usually three coats are sprayed. Stagger the overlap areas on vertical surfaces.
3. Clearcoat the entire vehicle.

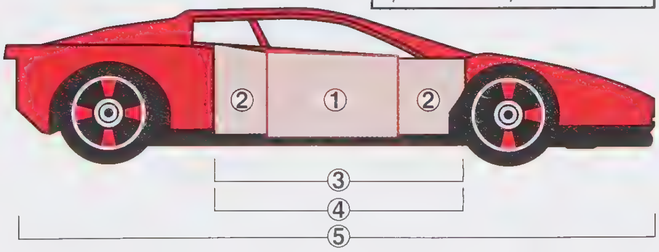
NOTE

Most, but not all, midcoats are pearl.

Blend

A tricoat blend requires that both the basecoat and midcoat be stepped out to hide any mismatch. In most cases, the midcoat is made of pearl, but candy paints and chameleon paints are also used as midcoats. Front or back blends can be made for the basecoat and midcoat. One problem encountered when blending pearl is that a pearl coat sprayed on top of the existing pearl may create a dark spot in the blend area. There are two ways to prevent this problem. The first method uses basecoat blender in the basecoat and midcoat. Basecoat blender is simply basecoat reducer. Mix one part ready-to-spray basecoat or midcoat with one part basecoat reducer. **Figure 30-24** shows a tricoat blend on the side of a vehicle. The first step is to prepare the entire side of the vehicle for a blend. Basecoat is applied to hide the undercoat on the entire replacement panel. The basecoat can be blended on the fender and quarter panel with a front blend. Overreduce the remaining basecoat and spray, at reduced pressure, 2" beyond the edge of the basecoat. This will make a gradual change in the basecoat. The blending of the midcoat will take place over this basecoat blend. Spray the proper number of midcoats using the front blend method. The edge of the first coat of midcoat should be the edge of the first coat of basecoat. Step out the next coats of midcoat slightly beyond the previous coats. Overreduce the midcoat and spray at a lower pressure 2" beyond the edge of the blend. Then clearcoat the entire side of the vehicle.

The second method of preventing dark spots in the blend area is a hybrid front and back blend of the midcoat. First, basecoat is sprayed to cover the undercoat. The basecoat can be front or back blended. The first coat of midcoat covers the basecoat. The second midcoat is sprayed 2" beyond the edge of the first coat. The third midcoat is sprayed 1" inch beyond the edge of the first midcoat. The last coat of midcoat is sprayed 3" beyond the edge of the first midcoat. This method is shown in **Figure 30-25**. In this example, a tricoat blend is made within a panel. The entire panel will be clearcoated. This example shows four coats of midcoat. This may or may not be the number of midcoats needed to match the color. Both methods prevent a dark edge around the repair.



Do not forget Color Blender options in Steps 2 & 4!

1. Apply basecoat to entire panel
2. Blend base color on quarter panel and fender
3. Apply midcoat to entire panel
4. Blend midcoat on fender and quarter panel
5. Clearcoat entire side

Figure 30-24. *Tricoat blend on the side of a vehicle. Allow flash time and tack the panel between coats. (PPG)*

Blending Strategies

This section will explain the blending strategy of typical solvent basecoat/clearcoat refinish operations. When a panel is painted, the adjacent panels should be blended. For example, if a fender is replaced, it will be painted. The adjacent panels—the door, hood, and front bumper— will be blended. As a general guideline, try to hide the blend.

Blend within a Repaired Panel

A contour, body line, or high crown is a good edge for hiding a blend. The colors will appear slightly different on each side of the body line or high crown, concealing a slight mismatch between the original paint and the refinish paint. A stripe or molding can also help hide a blend. A narrow area is a good place for a blend because the color difference will be less noticeable. Similarly, a wide panel gap may help hide a blend.

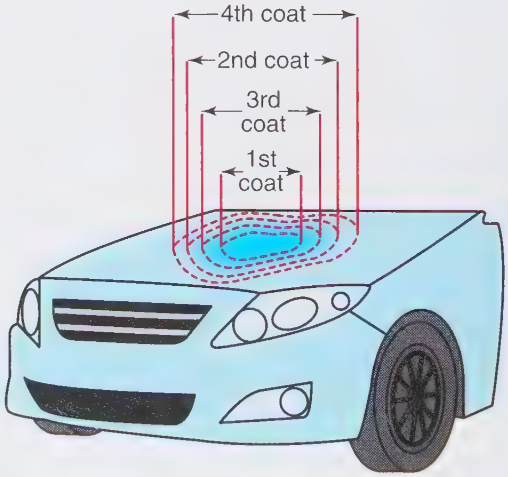


Figure 30-25. *Tricoat blend requires that both the basecoat and midcoat be stepped out to conceal any mismatch. Color matching depends on the number of midcoats. Front or back blends can be used.*

If a blend is made within a repaired panel, there must be enough room between the damage and the panel edge. A blend requires at least 6" between the edge of the surfacer or sealer and the edge of the panel, unless there is a panel contour or break to help hide the blend. If the edge of the undercoat is closer than 6" to the edge of the panel and there is no contour or break to hide the blend, the adjacent panel should be blended. **Figure 30-26** shows door repair where the blending can take place within the panel. **Figure 30-27** shows a repair that is too close to the edge of the panel. The fender shown in **Figure 30-27** must be blended. To save on the cost of materials, always try to keep the number of basecoats to a minimum. Basecoat is expensive.

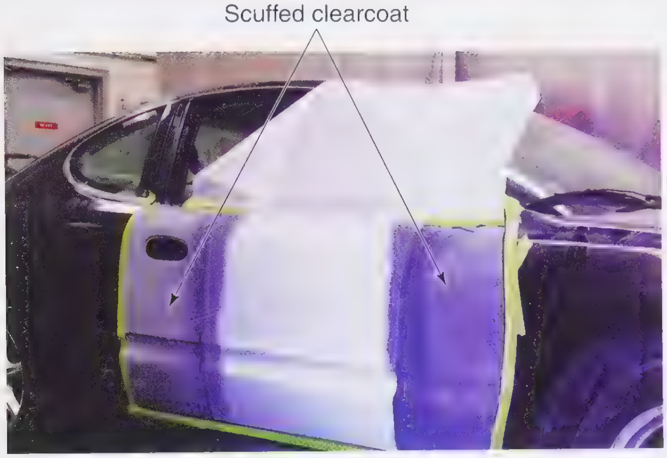


Figure 30-26. *A blend requires at least 6" between the edge of the undercoat and the edge of the panel. Here there is enough space between the undercoat and the edges of the door to keep the blend within the door. Adjacent panels are not blended.*

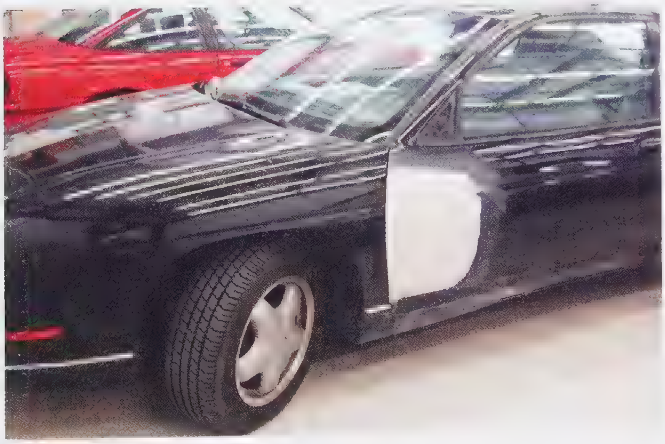


Figure 30-27. *If the edge of the undercoat is closer than 6" to the edge of the panel, the adjacent panel (in this case, the front fender) must be blended.*

The refinish clearcoat can be stepped out into the existing clearcoat. For example, if a small part of a panel will be blended and the rest clearcoated, the first coat of clear should cover the blend area only. The final (second) coat of clear should cover the entire panel. This method prevents excessive coats of clear and saves on materials.

A fender with blend is shown in **Figure 30-28A**. End the blend either in the crown or the body line, or stay 6" away from an adjacent painted panel. In all panels, a stripe or molding can be substituted for a body line, as long as the stripe or molding runs the entire length of the blend. A hood is shown in **Figure 30-28B**. The body line serves as the edge of the blend. If the middle of the hood is repaired, do not spray basecoat outside the body lines. If there is no body line on the hood, stay 6" away from the edge with the blend.

There are several ways to hide the blend on a door. See **Figure 30-28C**. The blend can be hidden by the body line, crown, stripe, or molding. It can also be hidden by the shadow of the door mirror. The rocker panel is so low and so highly crowned that color match is usually not a problem in this area. **Figure 30-28D** shows a quarter panel. Use the crown or body line to hide the blend.

A taillight will break up the color difference between the refinished quarter panel and the deck lid. The deck lid shown in **Figure 30-28E** has no longitudinal body line, so stay 6" away from the edge of the panel. The transverse contour can hide a blend. A uniside roof is shown in **Figure 30-28F**. Uniside vehicles often have a molding in the uniside/roof seam. Do not spray beyond the uniside/roof seam.

A bed side, **Figure 30-28G**, has a high crown area and a taillight at the rear. Unless the truck has a painted bed cover, there is no painted panel to match to at the top of the bed side. If only the front or rear portion of the bed side is to be painted, the blend can be made in the narrow area above the rear wheel. A bumper cover is shown in **Figure 30-28H**. The high crown areas at the corners of the bumper, as well as the narrow grille area, are good places to hide a blend.

Blending Adjacent Panels

The combinations of panels that can be painted on a vehicle vary widely. It is often necessary to blend adjacent panels. The following examples of blending adjacent panels involve applying 3 coats of basecoat while making a front blend. A back blend can also be made.

The first coat of the basecoat covers the replacement part and about 2" of any adjacent part. The second coat covers the replacement part and extends about 4" into the adjacent parts. The final coat covers the replacement part and extends about 6" into the adjacent parts. Contours or breaks in the adjacent parts can change spacing requirements.

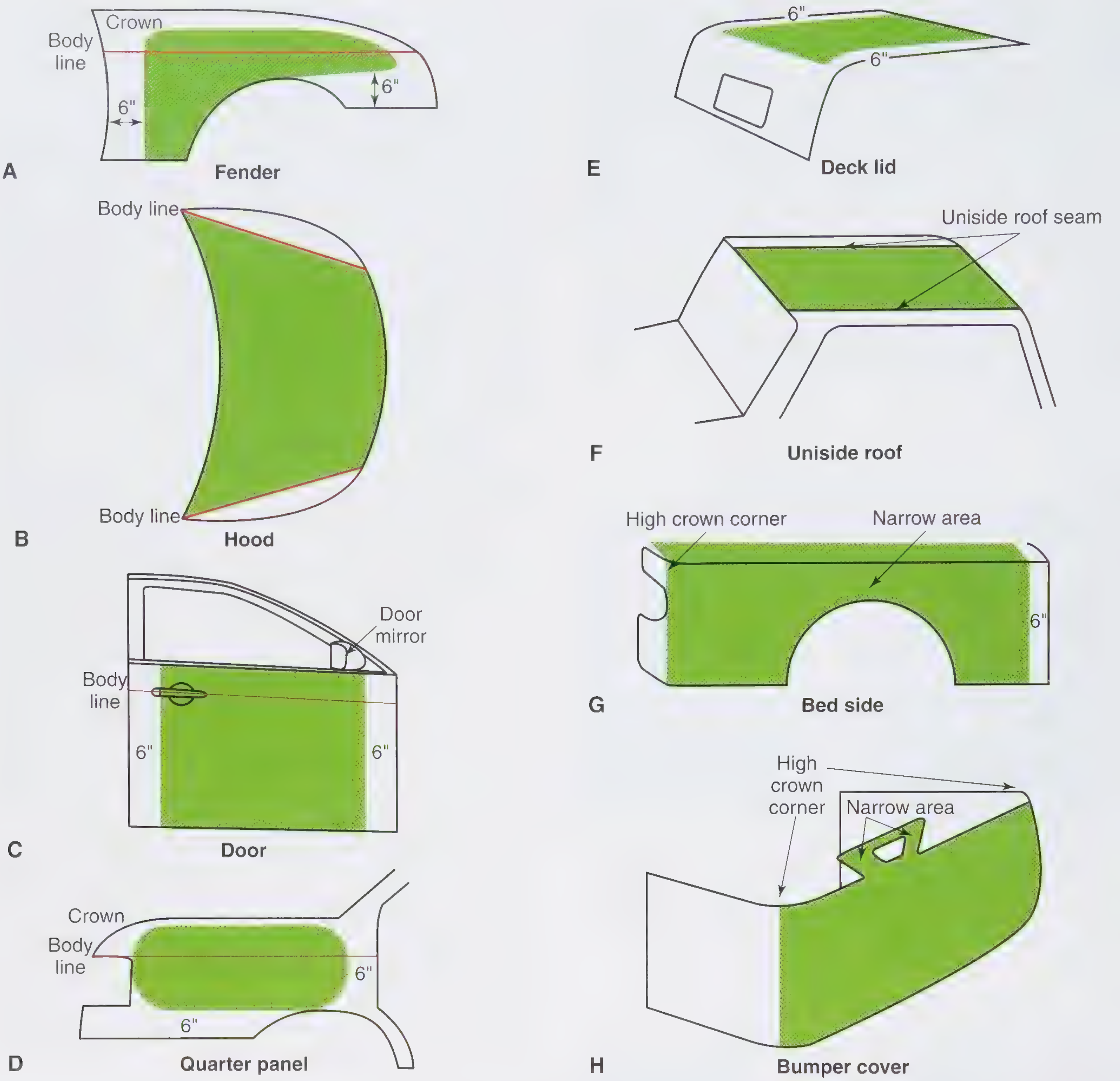

Crown
Body line
6"
6"
A
Fender
Body line
Body line
B
Hood
Door mirror
Body line
6"
6"
C
Door
Crown
Body line
6"
6"
D
Quarter panel
6"
6"
E
Deck lid
Uniside roof seam
F
Uniside roof
High crown corner
Narrow area
6"
G
Bed side
High crown corner
Narrow area
H
Bumper cover

Figure 30-28. *A—Use the crown, body line and edges to hide a blend in a fender. B—Use the body lines and edges to hide a blend in hood. C—Use the mirror, body line, and edges to hide a blend in a door. D—Use the body line, crown, and edges to hide a blend in a quarter panel. E—Use the edges to hide a blend in a deck lid. F—Use the seam to hide a blend in a uniside roof. G—Use the body line, crown, corner, narrow area, and edges to hide a blend in a bed side. H—Use the narrow area, body line, and corners to hide a blend in a bumper cover.*

All panels that are painted or blended are clearcoated. **Figure 30-29** shows a replacement front bumper cover. The front bumper cover blend does not extend beyond the corner of the bumper cover. The lower front portion of the fenders and front center of the hood are blended. Fender refinishing is shown in **Figure 30-30**. The door is sprayed so the blend ends under the door's mirror. The blend is extended 6" onto the hood. If the hood has a body line, the blend should not be sprayed across the body line. The windshield pillar on most vehicles will be adjacent to the fender. Usually there is enough of a gap that a slight mismatch in color is not noticeable. It may need to be blended if the color difference is great. If the vehicle has a cowl vent panel, it may need to be blended also. The rocker panel is usually not blended because it is low and out of sight. If the door has a wide molding,

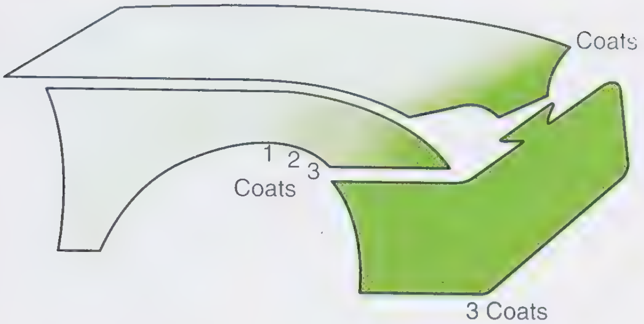


Figure 30-29. *Front bumper replacement may require blending the basecoat into the hood and fenders.*

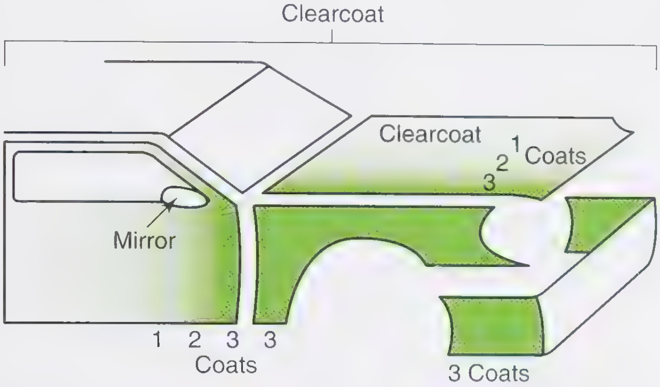


Figure 30-30. *Fender replacement may require blending the basecoat into the door, hood, and bumper cover.*

some shops only blend the door from the molding up, reasoning that the portion of the door below the molding is low enough that a color difference would be difficult to see.

A front view of a hood refinishing is shown in **Figure 30-31A**. The blend is made in the crown of the fenders. A vehicle with fenders that have a different shape is shown in **Figure 30-31B**. These fenders have a sharp contour at the edges. The blend is made so the last coat of base ends on this sharp contour. A body line in a fender is shown in **Figure 30-31C**. The blend ends at the body line. Blends in the crown and the body line should not extend from the fender to the door. This may create a mismatch at the door, so stay 6" away from the door with the blend. If the vehicle has a cowl vent panel, the entire cowl vent panel should be painted and not blended.

Figure 30-32 shows door refinishing on an extended cab pickup truck. The rear portion of the cab and the front fender are blended. Because the rocker panel is narrow and highly crowned, it is not blended because a color difference in this area would not be noticeable. The roof is not blended because on pickup trucks, the roof is so high it cannot be easily seen. Because the windshield pillar has high crown, a slight color difference between the window frame and the windshield pillar is generally not noticeable. The windshield pillar can be blended if the color difference is great.

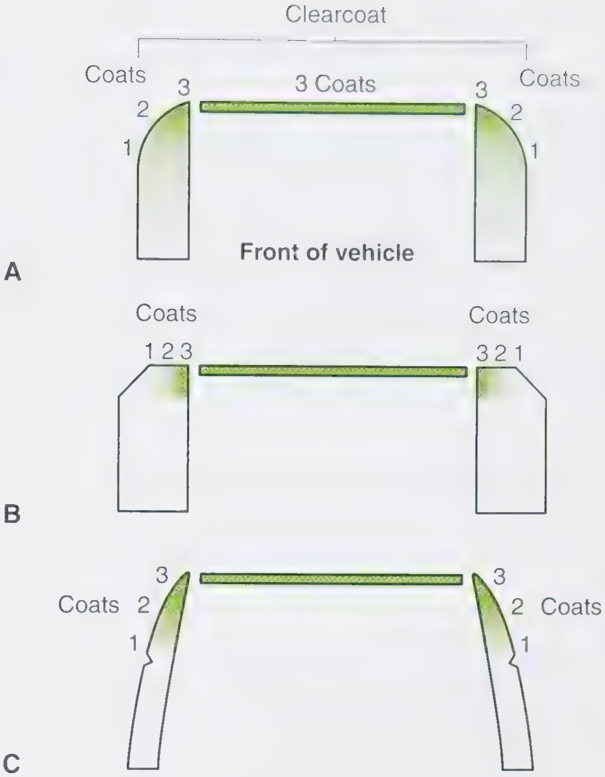


Figure 30-31. *A—When blending a fender for hood replacement, the basecoat is stepped onto the top of the fender. Use the crown of the fenders to hide the blend. B—This fender is flat on top. Keep the blend on the flat part of the fender, let the viewing angle hide the blend. C—This fender does not have much crown to hide the blend. Keep the blend above the body line.*

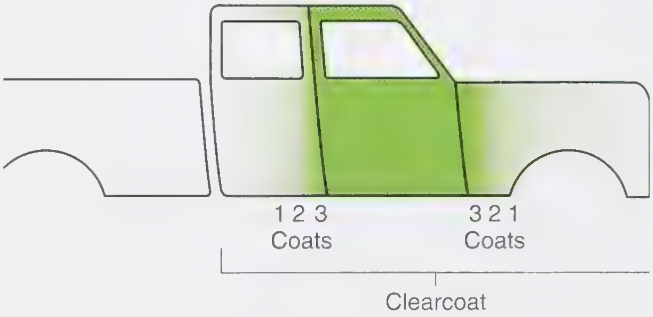


Figure 30-32. *Blend for this door extends into the cab corner and fender.*

Quarter panel refinishing on a uniside vehicle is shown in **Figure 30-33**. The deck lid, rear bumper, rear door, and sail panel are blended. On a uniside vehicle, it is much easier to clearcoat the uniside from the sail panel to the windshield pillar rather than trying to melt the clearcoat in the sail panel.

On a non-uniside vehicle there are two methods to apply clearcoat to the sail panel. The first, which is not durable and not covered by paint manufacturer's warranty, is to melt the clearcoat in the sail panel. The other method is to clearcoat the replacement quarter panel, the roof and the opposite quarter panel. This will put at least one full coat of clear over the entire repair area.

Baking

Baking is the process of using heat to accelerate the rate of cure of fresh paint. Urethane paint and catalyzed enamel cure by evaporation of solvent and crosslinking of hardener.

Heat will increase the rate of both evaporation and crosslinking. **Figure 30-34** shows a spray booth capable of heating the air to 200°F (93.3°C). Some shops choose to rapidly bake a vehicle at 200°F for five minutes and then hold it at 180°F (82.2°C) for twenty minutes. Other shops heat the vehicle to 140°F (60°C) for thirty minutes. The paint manufacturer will give recommendations on baking temperature and baking time.

As paint dries, the solvent will evaporate. Most of this evaporation takes place during spraying and immediately after spraying. The concentration of solvent in the air during drying will not be nearly as great as the concentration of solvent in air during spraying.

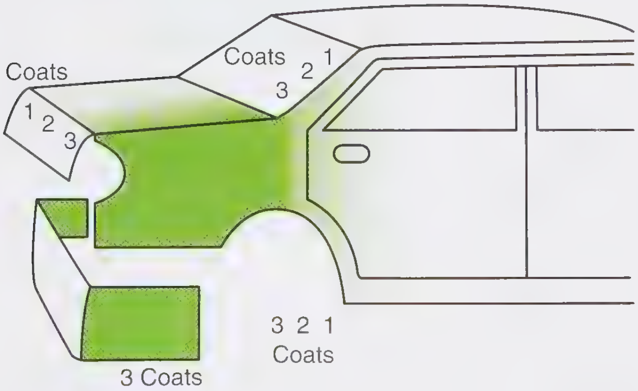


Figure 30-33. *Quarter panel replacement blends are made in the sail panel, rear door, deck lid, and rocker panel. Notice that the rear bumper cover is not blended because the corner will hide a color difference.*

Figure 30-34. *This baking spray booth is capable of heating air to 200°F (93.3°C)*

As the vehicle is sprayed, the exhaust fan runs at a rate sufficient to remove enough solvent-laden air to keep the spray booth environment safe. After the vehicle is painted, but before the spray booth temperature is raised, all the solvent-laden air is purged from the spray booth by the exhaust fans at the same rate as during the spraying process. Normal purge times are 1–3 minutes.

When an exhaust fan is running, replacement air from outside the building is pulled into the spray booth. This air is known as ***make up air***. If the outside temperature is below 60°F (15.5°C), make up air must be heated to at least 60°F. During baking, the exhaust fan runs slower because solvent levels are lower. Also, heating make up air is expensive, so you don't want to vent the booth too quickly.

During baking, vehicle temperature can be monitored with either a surface thermometer or an infrared thermometer. The surface thermometer is attached to the vehicle near the painted area. Do not attach the thermometer to the fresh paint. The infrared thermometer can be pointed at the vehicle to determine surface temperature. The upper surfaces of the vehicle may be warmer than the lower surfaces.

WARNING

The painter should not enter the booth during the baking cycle. Never allow temperature-sensitive equipment to remain in the booth while baking. After baking, the vehicle should be allowed to cool before it is handled.

Another method of baking is to use infrared energy to raise the surface temperature of the paint. This is done outside the spray booth with portable equipment or in a room adjacent to the spray booth with fixed equipment.

As with heated-air curing, there should be a period of a few minutes between the end of spraying and the beginning of infrared curing. The infrared unit is placed at the specified distance from the panel or panels for a specified amount of time. Typical infrared bake times are less than 30 minutes. A drawback to this method of baking is the vehicle must be moved from the spray booth while the paint is wet, increasing the chances of contaminating wet paint and ruining the job. Another limitation to portable IR equipment is that only one or two panels can be treated at a time. This would be impractical for a complete refinish or an entire side of a vehicle. One benefit to infrared curing is that the energy cost to operate the infrared unit is less than the cost of heating make up air.

CAUTION

After a vehicle has been baked, do not remove it from the booth until it has cooled down.

Removing Masking Materials

Masking materials, such as tape, paper, and plastic, should be removed after the painted vehicle is moved from the spray booth. If the vehicle has not been baked, the vehicle should be removed from the spray booth only after the clearcoat's dust-free time has passed. ***Dust-free time*** is the number of minutes required for the paint to cure to a point where dirt will no longer stick. For example, if the clearcoat dust-free time is 15 minutes, the painted vehicle should remain in the spray booth with the exhaust fan running for at least 15 minutes after painting operations are completed. After the dust-free time has elapsed, the vehicle can be safely moved out of the spray booth and into the shop.

Even after the dust-free time has passed, contamination can still cause problems with uncured paint. Avoid placing the vehicle in an area where contamination, such as sanding dust or water spray, can land on it. An unbaked vehicle can be moved outside as long as the outside temperature is over 60° F (15.5°C). Catalyzed paint, such as clearcoat, cannot crosslink and cure at temperatures below 60°F.

CAUTION

When removing masking materials, always pull the masking away from the fresh paint. Do not touch the fresh paint with the masking materials or your hands.

Troubleshooting

Problems can arise during painting and immediately after painting. In most cases, preventing a problem is much easier than repairing the problem. When problems do arise, the painter must be able to solve them as quickly as possible.

A ***run*** is caused by too much paint applied to a surface. See **Figure 30-35**. Too much paint can be the result of moving the spray gun too slowly, holding the gun too closely to the surface, overlapping too much, improperly adjusting the spray gun, or by a combination of all these factors. If the run is in the first coat of base, immediately wipe off the excess paint with a lint-free cloth soaked with wax-and-grease remover, **Figure 30-36**.

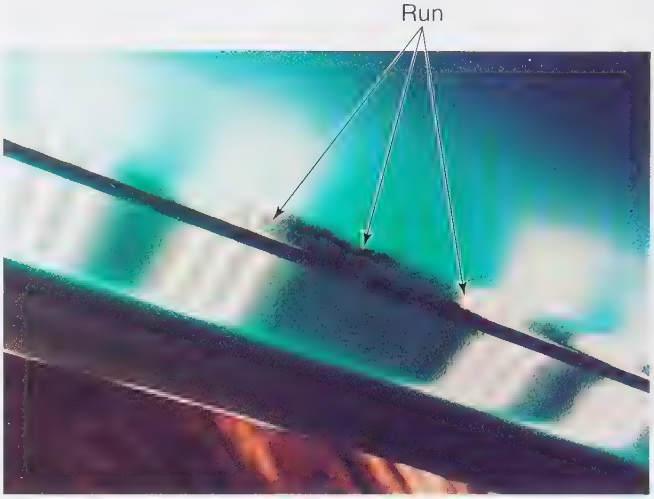


Figure 30-35. *Runs are caused by too much paint in the fan, moving too slow, or spraying too close to the surface.*

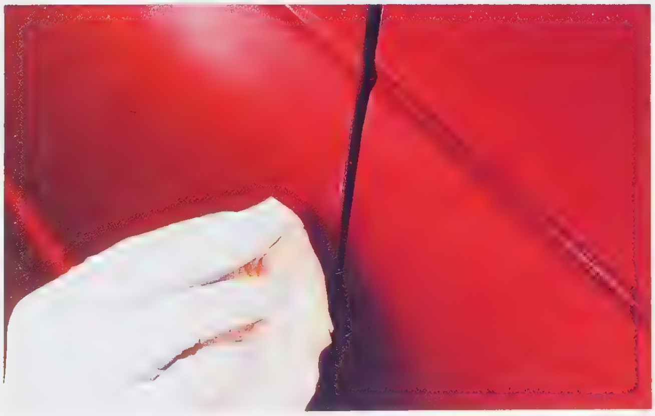


Figure 30-36. *If a run occurs in the first coat of basecoat, the excess paint can be wiped off with a lint-free rag soaked with wax-and-grease remover.*

The wax-and-grease remover acts as a solvent, dissolving the basecoat. This will remove the paint, but it can leave an edge. If an edge cannot be felt, the next coats of base should cover the defect. If an edge can be felt, it should be sanded down after the paint has dried. The edge can be sanded with 1000-grit sandpaper soaked in wax-and-grease remover. Wax-and-grease remover is a better lubricant than water. Lightly sand until the edge can no longer be felt.

If the run is in the second or third coat of base, the paint should be allowed to dry for about ten minutes. The excess paint can then be sanded with 1000-grit sandpaper soaked in wax-and-grease remover. Lightly sand the excess paint as shown in **Figure 30-37**. Do not dig into the paint. Gradually work down the surface. If the run is on the last coat of base, spray on one more coat of base to cover the sanded area. If a run is made in the clearcoat, continue spraying. Clearcoat runs can be removed by sanding and buffing during the detailing process.

Dirt in the basecoat can be removed by tacking between coats. Dirt that cannot be removed by tacking can be sanded out with 1000-grit sandpaper soaked in wax-and-grease remover. Another way to remove dirt is to pick it out with tweezers or a needle. See **Figure 30-38**. If tweezers are used, there may be an edge where the dirt was removed. If the edge can be felt, it should be sanded out. Dirt in the clearcoat can be removed with tweezers or it can be removed by buffing during detailing.

Fish eyes are caused by silicone contamination of the paint surface. See **Figure 30-39**. If fish eyes are going to show up, they will be evident as soon as the contaminated area is sprayed. It is much easier to prevent fish eyes than to repair them. To prevent fish eyes, thoroughly clean all refinish surfaces with wax-and-grease remover.

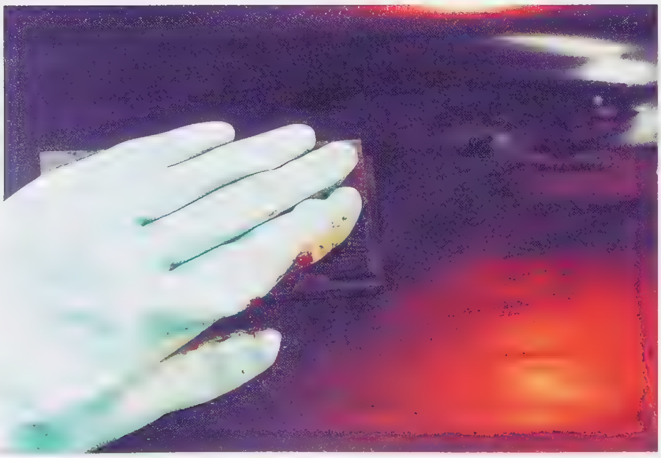


Figure 30-37. *Careful wet sanding with 1000-grit soaked in wax-and-grease remover can remove a run or contamination in basecoat.*

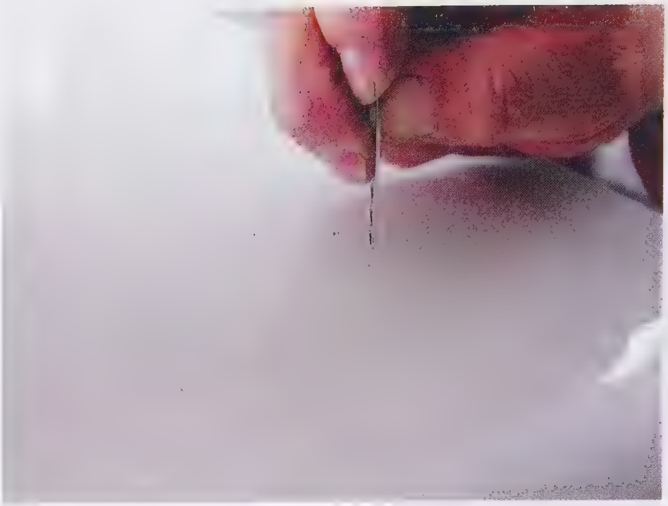


Figure 30-38. *Tweezers can be used to pick dirt or lint out of wet paint.*

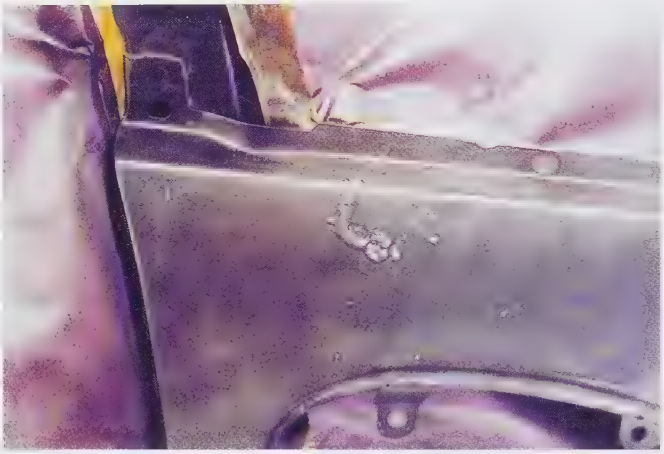


Figure 30-39. *Fish eyes are caused by painting over surface contaminants such as grease, oil, or silicone. These fish eyes showed up in the first coat of base. Notice the difference in sizes.*

If a few fish eyes are present in the basecoat, they can be filled with dry spray. A dry spray coat dusted over the fish eye area may bridge the problem. If the fish eyes cannot be filled with dry spray, allow the basecoat to dry for ten minutes and then clean the area with wax-and-grease remover. Sand out the fish eyes with 1000-grit sandpaper soaked in wax-and-grease remover. Then clean the area again with wax-and-grease remover and dry it thoroughly.

Mottling is a common problem on horizontal surfaces. Mottling means the metallic flake in the paint is unevenly distributed. Mottled paint looks blotchy, with light and dark areas. See **Figure 30-40**. A dirty air cap can cause mottling. If mottling is present, clean the air cap. If mottling remains

Figure 30-40. *Uneven distribution of metallic flakes results in mottling. In this example, the dark area is mottling.*

Figure 30-41. *Lifting occurs when refinish paint chemically reacts with the paint layer below it.*

after cleaning, there are two ways to correct the problem. The first way is to spray a dry coat over the last coat of base. The dry coat will lock the metallic in place. A dry coat can be made by decreasing the amount of material at the spray gun, increasing the distance between the spray gun and the surface, or increasing travel speed. The other way to correct mottling is to spray the last coat of basecoat at an angle to the previous coats. Some paint manufacturers recommend a ***drop coat*** as the last coat of basecoat. The drop coat is used to correct the orientation of the aluminum flakes in the metallic paint. A drop coat is sprayed at half the normal air pressure, with all other aspects of spray technique remaining the same.

Lifting is caused by a chemical reaction between an existing lacquer or thermoplastic paint layer and the solvent in the refinish paint. Lifting looks like shriveled paint. If lifting is going to occur, it will be seen when the first coat of paint is applied to an area. Lifting usually occurs over a previous repair, especially a featheredged area. Lifting may also occur when spraying basecoat over an uncured clearcoat, such as when correcting a mistake that was made during painting. See **Figure 30-41**.

The cure for lifting is to create a barrier between the refinish paint and the incompatible lacquer or thermoplastic paint. With the vehicle in the booth, allow the basecoat to dry for ten minutes. Sand the problem area smooth with 1000-grit paper soaked in wax-and-grease remover. Adjust the spray gun for a dry spray and apply several dry coats over the lifted area, allowing flash time between coats. This should build up a dry barrier over the lacquer or thermoplastic paint. After applying the dry coats, spray on coats of base as usual. If lifting continues, again allow the basecoat to dry. Sand down the lifted area until smooth, and then spray on one coat of a waterborne primer. The waterborne primer does not contain enough solvent to cause an adverse reaction with the lacquer or thermoplastic layer. Scuff/sand the waterborne primer carefully. If you sand through the primer, the lifting problem will come back. The solvent from the refinish paint will not penetrate the waterborne primer.

NOTE

The waterborne primer may take up to 24 hours to dry. Check the manufacturer's instructions before applying the basecoat.

Solvent pop is caused by trapped solvents escaping through a partially cured paint film. See **Figure 30-42**.

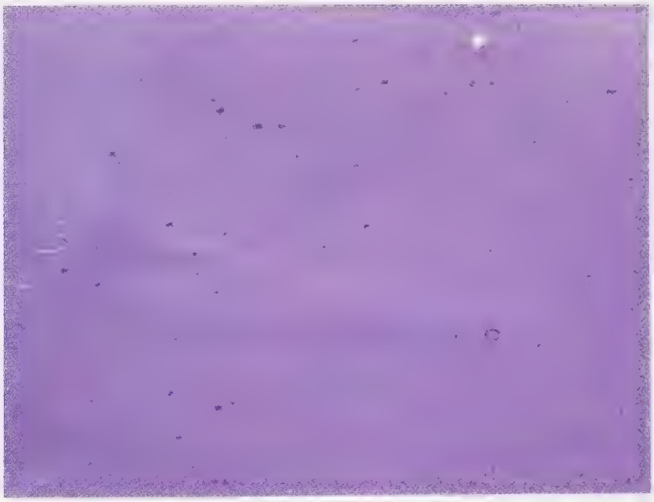


Figure 30-42. *Solvent pop is caused by trapped solvents escaping through a partially cured paint film. Observe recommended flash times to avoid this problem.*

If coats of paint are sprayed without observing recommended flash times, if the exhaust fan is not moving enough air, or if a coat is sprayed too heavily, the paint surface may skin over before all the solvent has evaporated. The solvent will continue to evaporate by breaking through the paint skin, leaving a hole. Small solvent pop holes can be removed by sanding after one hour of drying time. Always sand lightly with 1000-grit sandpaper and wax-and-grease remover. If sanding with 1000-grit does not remove the pops, switch to 400-grit sandpaper. The coarser paper may require that a sealer or surfacer be applied before spraying the basecoat.

Blushing causes the paint surface to look dull, **Figure 30-43**. It is difficult to detect because the basecoat dries to a dull finish even when blushing is not present. Blushing is caused by moisture trapped in the paint film, and high humidity is the likely reason. If blushing is present, warm the paint surface to dry out the moisture and respray. A slower drying reducer may be used to give trapped moisture enough time to escape from the paint before it skins over.

Orange peel, shown in **Figure 30-44**, is a term used to describe an uneven surface texture. Orange peel literally looks like the surface of an orange. Small bumps distort light or any image reflected in the panel. There are degrees of orange peel. For example, OEM paint has a small amount of orange peel. More than an OEM-level of orange peel on a repainted vehicle is a sign of a poor quality workmanship. On the other hand, a show car that has been properly prepped, painted, and buffed has no orange peel. A high-quality paint job would reflect an extremely sharp, mirror-like image.

Orange peel is caused by improper spray gun adjustments or incorrect spray technique. In either instance, too much paint is applied to the surface. Adjust the fluid control knob to decrease the amount of paint, or increase air pressure by 5 lbs. Improper spray gun technique can be another cause of orange peel. Moving the spray gun farther away from the surface or moving the gun across the panels at a faster rate will often eliminate the problem.

Figure 30-43. *Blushing makes the paint look dull. It is caused by moisture trapped in the paint, and high humidity is the likely cause.*

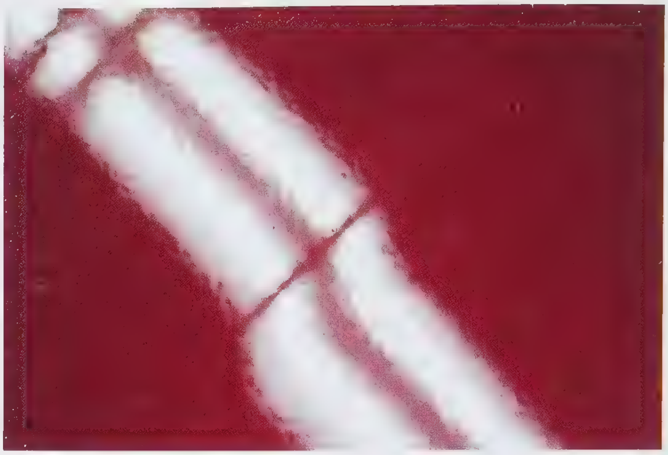


Figure 30-44. *Orange peel is a bumpy, nubby surface that looks like the skin of an orange. These small bumps distort light reflection. Orange peel can be removed from clearcoat by color sanding and buffing.*

If orange peel is excessive in the basecoat, the paint should be allowed to dry and sanded with 1000-grit paper lubricated with wax-and-grease remover. After sanding out the roughness, apply additional basecoats. If the orange peel in the clearcoat is excessive, color sanding and buffing will eliminate it.

Scratches, pinholes, or other signs of poor surface preparation may show up in the basecoat. Minor scratches can be bridged with a dry coat of base. If this does not work, allow the basecoat to dry and sand out the scratches or pinholes. If necessary, two-part spot putty can be used to fill the voids. If putty is used, the area should be sprayed with sealer before the basecoat is reapplied.

When masking tape is applied to the refinish panel, there is always a chance that the paint will adhere better to the tape than to the panel. When this occurs, paint will lift from the panel as the masking tape is removed. This problem is known as bridging. There are two ways to avoid bridging. The first way is to use fine-line tape, which has a slicker surface than masking tape. Paint will not adhere as readily to fine-line tape as it will to a properly sanded panel. The other way to prevent bridging is to always leave a gap between the masking tape and the edge of the spray area. When the masking tape is removed, the paint will separate in the gap area and not lift off the panel.

To prevent bridging, always sand the panel to give the refinish paint a good surface to adhere to. Remove the masking tape carefully, always watching for bridging. If refinish paint is pulled off the panel, the area will need to be featheredged, filled, and refinished.

Dry spray occurs when not enough paint is applied to wet the surface. Dry spray is more noticeable in clearcoat than basecoat and is often mistaken for orange peel. Prevent dry spray by concentrating on spray technique. A common cause is not maintaining the required 50% overlap. When spraying the second coat of clear, it can be difficult to keep track of overlaps because the panels will be shiny from the first coat of clear. If an area is missed and not covered by an overlap, it will look rough and dry. It takes a high level of concentration to make sure every part of the panel is overlapped properly. Spraying clearcoat is a balance between applying enough material to avoid dry spray while not applying so much that you create runs.

Sand scratch swelling, **Figure 30-45**, can result from spraying basecoat over a surface that is laden with solvent. If, for example, a part is sprayed with basecoat and there is a problem that requires the basecoat to be sanded, care must be taken when cleaning the part with wax-and-grease remover before spraying it again with basecoat. The sanded basecoat can absorb the wax-and-grease remover. The solvent from the wax-and-grease remover, in addition to the reducer in the basecoat, will soften and swell the surface, filling scratches. Subsequent basecoats will soak into the sanded basecoat and cause the sand scratches to swell. The swollen surfacer shows the outline of scratches in the basecoat. Repair sand scratch swelling by first allowing the part to dry until the solvents evaporate. Then lightly scuff the basecoat with 1000-grit dry sandpaper and apply additional coats of basecoat.

Water spots are caused by water droplets that fall on and contaminate fresh paint. Fresh paint may remain soft for several hours after it is applied. Water droplets landing on fresh paint make a shallow crater in the paint or cause discoloration when minerals in the water remain after the water has evaporated. If either of these happen, the remedy is the same. Allow the paint to cure, color sand with 1500-grit sandpaper, and buff the surface. If this does not correct the problem, scuff sand the surface with 1000-grit sandpaper and repaint.

Solvent or water trapped under the dried paint film causes ***blistering***. See **Figure 30-46**. The most common cause of blistering is priming and painting over improperly prepared, rusty metal. Rust may penetrate the metal, creating a tiny hole. After the metal is primed and painted, the rust hole allows moisture from the back side of the panel to accumulate under the paint, causing water-filled blisters. The blisters may show up within a few hours of painting. Blistering caused by trapped water can be repaired by stripping the blistered area to bare metal and properly treating the rust. Proper treatment involves cutting out the rusted area to solid metal and welding or bonding a patch in place. Apply self-etching primer, followed by surfacer, basecoat, and clearcoat in the normal manner. Also, apply self-etching primer to the back of the panel.

Blistering can also be caused by trapped solvents, much like solvent pop. Instead of making craters, the trapped solvent forms blisters. The first step in repairing solvent-formed blisters is to allow the paint to cure. Next featheredge the blisters and apply primer and surfacer. Finish with basecoat and clearcoat.

Mapping is a surface defect that shows the contour outline of a body filler repair or featheredging operation. Mapping is caused by improper featheredging of body filler or paint layers. Mapping can be corrected by block sanding the defect all the way down to the body filler to identify low areas. Low areas are filled with body filler or surfacer and block sanded. The repair is then repainted.

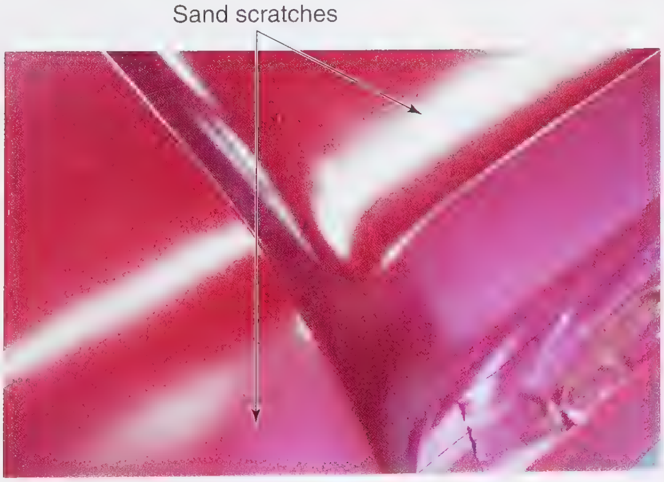


Figure 30-45. *These sand scratches showed up in the first coat of basecoat and are a sure sign of poor surface preparation.*

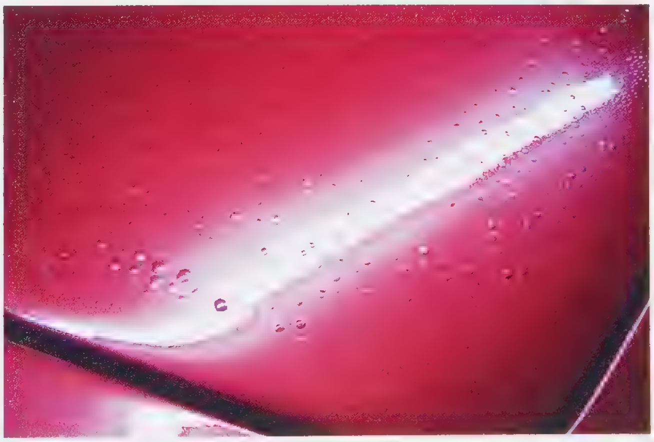


Figure 30-46. *These blisters contain trapped solvent. Featheredging and repainting is the only way to repair a serious defect such as this.*

Sand scratches or any type of gouge in body filler is similar to mapping in that their outlines are visible in the paint. They are caused by poor surface preparation and are much easier to prevent than to correct. Sand scratches are caused by sanding the surface with a grit of sandpaper that the paint cannot fill. For example, if the surfacer was sanded with 180-grit sandpaper but the paint manufacturer recommends 600-grit sanding, the paint will not fill the 180-grit sand scratches. Gouges result from not sanding out deep 40- or 80-grit sandpaper scratches or not filling pinholes or other surface defects in body filler. The scratches or gouges can be seen and felt. To correct these defects, remove the paint from the problem area and either fill or sand out the scratches or gouges. Once the scratches or gouges cannot be detected, apply primer and surfacer as required. Follow with application of basecoat and clearcoat.

Summary

- The body shop determines the level of surface preparation.
- The level of surface preparation depends on how many components are removed before painting.
- Dirt, dust, sand, and lint are just a few of the contaminants present in the shop environment.
- Sources of paint contamination are: vehicle, painter, spray gun, air hose, masking, spray booth, and paint.
- Baking rapidly dries/cures paint.
- Single-stage paint can be sprayed as a complete, panel, melt, or two-tone.
- Basecoat/clearcoat paint can be sprayed as a complete, panel, blend, melt, or two-tone.
- Tricoat paint can be sprayed as a complete, blend, or melt.
- A melt is a thin application of clearcoat used to make an invisible repair in a basecoat/clearcoat paint system.
- All colors must be sprayed to hiding.
- When blending within a panel, use a body line or stripe as a break line.
- When spraying multiple panels, blend adjacent panels.
- Clearcoat can be difficult to spray because it goes on clear, making it hard to determine which areas have already been covered.
- Common refinish problems include runs, dirt, fish eyes, mottling, lifting, solvent pop, blushing, orange peel, scratches, and bridging.

Review Questions

Please do not write in this textbook. Place your answer on a separate sheet of paper.

1. What is the greatest source of contamination when spraying a vehicle?
2. List and explain four sources of contamination in a paint job.
3. Explain Level 1 surface preparation.
4. Obstructions are removed in Level 2 surface preparation.
5. Level ______ surface preparation methods require the most labor.
6. After a vehicle is painted, the solvent-laden air is ______ before baking.
7. Which type of paint is not available in OEM colors?
8. Explain the purpose of applying a tack coat.
9. Basecoat requires a tack coat. True or False?
10. Explain the concept of flash time.
11. Explain why some metallic paints require a mist coat after the last medium-wet coat is applied.
12. List two colors that are poor hiders.
13. The basecoat cannot be tacked off before applying clearcoat. True or False?
14. Explain how to make a front blend.
15. Explain how to make a melt using the one-gun method.
16. When blending, fanning the spray gun at the end of a stroke will cause a halo effect. True or False?
17. Which is more durable, a melt or a blend?
18. A replacement fender is to be painted. Which panels should be blended?
19. ______ are caused by silicone contamination.
20. Excessive orange peel is caused by improper spray gun adjustments. True or False?

ASE-Type Questions

1. Folds in masking paper will trap and hide contaminants that can be blown into the wet paint by air from the spray gun. When should folds in the masking paper be taped over with masking tape?
   (A) When spraying basecoat.
   (B) When spraying clearcoat.
   (C) Not necessary to tape over folds when wearing a clean paint suit.
   (D) Always tape over all masking paper folds.

2. A clean paint suit will prevent ______ from the painter's own clothes from dislodging and landing in the wet paint.
   (A) contaminants
   (B) paint
   (C) overspray
   (D) orange peel
3. Sources of contamination in wet paint are being discussed. Technician A says the air hose is a potential source of contamination. Technician B says the spray gun is a potential source of contamination. Who is right?
   (A) A only.
   (B) B only.
   (C) Both A and B.
   (D) Neither A nor B.
4. The time it takes for solvents in freshly applied paint to evaporate, leaving the paint dry enough to touch or tack off, is called ______.
   (A) tack off time
   (B) flash time
   (C) mottling
   (D) overtime
5. The rough surface left by a tack coat allows the wet coats that follow to adhere without ______.
   (A) blistering
   (B) running
   (C) mottling
   (D) nib sanding
6. All of the following methods are ways to eliminate dirt in basecoat EXCEPT:
   (A) painting over it.
   (B) pulling it out with tweezers.
   (C) sanding it out.
   (D) tacking it out.
7. The two most common problems when spraying clearcoat are ______.
   (A) dry spray and orange peel
   (B) silicone contamination
   (C) solvent pop and chalking
   (D) dirt and dust in the clearcoat
8. A vehicle is to be clearcoated. Technician A says to spray at least four coats of clear for maximum durability. Technician B says to sand the basecoat before spraying the clearcoat. Who is right?
   (A) A only.
   (B) B only.
   (C) Both A and B.
   (D) Neither A nor B.
9. Which of the following terms means that the entire vehicle is refinished?
   (A) Total coverage.
   (B) Blending.
   (C) Melting.
   (D) Complete.
10. Which of the following problems is caused by improper triggering when blending metallic basecoat?
   (A) Lifting.
   (B) Solvent pop.
   (C) Blushing.
   (D) Halo.
11. Technician A says that in a back blend, each coat of base is stepped out 2" from the edge of the previous coat. Technician B says that on a back blend, each coat of base is stepped in 2" from the edge of the previous coat. Who is right?
   (A) A only.
   (B) B only.
   (C) Both A and B.
   (D) Neither A nor B.
12. A sail panel will be melted. Technician A says to use the two-gun method. Technician B says to use the one-gun method. Who is right?
   (A) A only.
   (B) B only.
   (C) Both A and B.
   (D) Neither A nor B.
13. A two-tone basecoat/clearcoat vehicle needs to be refinished. Technician A says to spray one basecoat color, mask it, spray the other basecoat, and then clearcoat both colors at the same time. Technician B says to spray one basecoat color, clear it, and then spray the other basecoat color and clear it. Who is right?
   (A) A only.
   (B) B only.
   (C) Both A and B.
   (D) Neither A nor B.
14. At minimum, how much distance between the surfacer or sealer and panel edge is required for panel blending?
   (A) 1".
   (B) 2".
   (C) 3".
   (D) 6".
15. A replacement hood is to be painted. Technician A says to blend the fenders. Technician B says to blend the adjacent front bumper. Who is right?
   (A) A only.
   (B) B only.
   (C) Both A and B.
   (D) Neither A nor B.
16. Technician A says that no one should enter the booth during the bake cycle. Technician B says that the baking temperature is at least 300°F. Who is right?
   (A) A only.
   (B) B only.
   (C) Both A and B.
   (D) Neither A nor B.

17. All of the following can cause a run EXCEPT:
    (A) spraying too closely.
    (B) spraying from too far away.
    (C) too much overlap.
    (D) travel speed too slow.
18. Basecoat runs need to be sanded out. Technician A says to use water and 1000-grit sandpaper. Technician B says to use wax-and-grease remover and 1000-grit sandpaper. Who is right?
    (A) A only.
    (B) B only.
    (C) Both A and B.
    (D) Neither A nor B.
19. Which of the following surface defects is caused by moisture trapped in the paint film?
    (A) Mottling.
    (B) Lifting.
    (C) Blushing.
    (D) Orange peel.
20. Which of the following refinish problems may require a coat of waterborne primer?
    (A) Mottling.
    (B) Lifting.
    (C) Solvent pop.
    (D) Blushing.

Chapter 31

Specialty Painting

Objectives

After studying this chapter, you will be able to:

- Identify an olefin-containing plastic.
- Recognize the importance of obtaining and following the paint manufacturer's recommendations for plastic refinishing.
- Understand why mold release agent must be removed before refinishing.
- List the steps in prepping and painting a new, unprimed, plastic part.
- List the steps in prepping and painting a new, primed plastic part.
- List the steps in prepping and painting a repaired plastic part.
- Know when to use flex agent.
- Explain "custom painting" techniques.

Technical Terms

adhesion promoter
artistic masking
bull's-eye
candy color
fading
flex agent
flexible plastics
float test
ghost flames
ghosting
high-metallic color
highlighting
marbleizing
mold release agent
rigid plastics
semi-rigid plastics
shading
simulated chrome
stenciling

Introduction

There are many kinds of plastics used on late-model vehicles. Painting some types of plastic, such as sheet molded compound (SMC) or fiberglass reinforced plastic (FRP), is no different than painting steel. Other types of plastics, such as olefin plastics, may require surface treatment for proper paint adhesion. When painting flexible plastics, such as urethanes, additives must be mixed into the paint so it can bend without cracking when the plastic part is deformed during a collision. Finally, some molded-in-color plastics may be unpaintable because paint will not adhere to the surface.

Plastic refinishing procedures depend on the paint system being used. Different paint manufacturers have different recommendations. The guidelines presented in this chapter may not apply to all paint systems. Always follow the specific techniques recommended by the paint manufacturer.

Plastic Types and Characteristics

The automotive industry is increasingly moving toward plastic components. New materials and technologies have been developed to improve the surface quality of automotive components while lowering production costs. With the wide variety of plastics used on vehicles, there are a few new terms and concepts that must be understood.

Plastic parts are classified as flexible, semi-rigid, and rigid. ***Flexible plastics*** include urethane (PUR) and thermoplastic olefin (TPO and TEO). TPO, for example, has become the material of choice for exterior automotive applications such as bumpers. TPO and polypropylene (PP) are the fastest growing due to their mechanical properties and their advantages relative to recycling.

Semi-rigid plastics include polypropylene (PP), polycarbonate (PC), acrylonitrile butadiene styrene (ABS), vinyl, GTX, and Pulse. PP is rugged, resistant to fatigue, lightweight, and resistant to many chemical solvents, bases, and acids. It is currently being used to manufacture interiors, consoles, dashboards, door panels, radiator shrouds, and fans. PC is a clear plastic used for headlight covers and taillights. ABS is a rigid, impact- and heat-resistant plastic that offers excellent abrasion resistance. It has replaced traditional metal materials due to ease of forming, increased durability, and resistance to weathering. ABS can be found in interior parts, as well as exterior trim.

GTX is a lightweight, impact resistant, and recyclable resin. It is being used in the automobile industry to trim down the weight of vehicles to boost fuel economy. GTX is conductive. This allows for high paint transfer efficiency and eliminates the need for a conductive primer. Pulse is an engineered resin. It offers high heat resistance, high impact strength, and is currently being used in automotive exterior trim applications.

Rigid plastics include sheet molded compound (SMC) and fiberglass reinforced plastic (FRP). SMC is a versatile plastic currently used in bumpers, fenders, exterior and interior panels, structural elements, and more recently, high-temperature underhood parts. SMC can handle E coat application at 300°–400°F (148°–204°C). Vehicle manufacturers continue to increase their FRP content to reduce weight and save money. Products made from this lightweight material outperform and cost less than the products they replace. Hoods, tailgates, decklids, and truck beds are being made from FRP.

Flexible Plastic Parts

Flexible and semi-rigid plastic parts are designed to deform under force and pop back into shape when the force is released. Most bumper covers are designed to do this. Unfortunately, automotive paint does not have this ability to bend and will crack and fail. See **Figure 31-1**. To avoid this problem, a flex agent can be added to some paints. The ***flex agent*** changes the characteristics of the paint so it will bend without cracking when the flexible part is deformed.

Paint manufacturers have very specific instructions as to how and when flex agent should be used. For successful plastic painting, follow the paint manufacturer's recommendations carefully. Flex agent may be required in the surfacer and in the clearcoat. In some paint systems, the sealer also requires a flex agent. Some clearcoats do not require flex agent. Properly mixed, these clearcoats are elastic enough not to crack on impact.

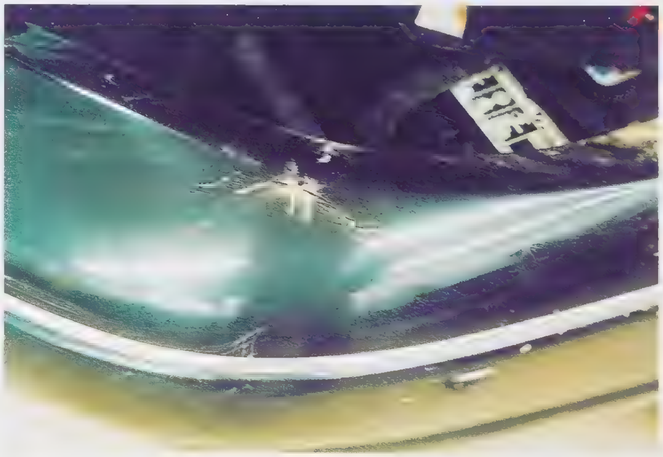


Figure 31-1. *The paint on this plastic bumper has been cracked by an impact.*

Bumper covers and other flexible plastic parts should be test-fit before painting. Some plastic parts are easy to install. Others, such as bumper covers, must be stretched to fit around the bumper reinforcement. A poor fitting part can be returned. If the part is painted before it is fitted and it does not fit properly, it cannot be returned to the supplier for replacement. The technician will have wasted time painting the ill-fitting part. Most shops paint bumper covers off the vehicle. When installing painted parts, there is always the possibility of scratching the paint. By test-fitting the part before painting, you can also determine how difficult the part will be to install. Parts that require stretching during assembly, such as bumper covers installed on a reinforcement, should be put together before painting. If the bumper is painted before installation, the technician will not run the risk of damaging the paint during installation. However, this will also make the bumper cover/reinforcement assembly heavy and unwieldy. Be careful when handling it.

The primer used on bare plastic is designed to help paint adhere. Plastic primer is also called ***adhesion promoter***. Plastic-containing olefins require a change in surface chemistry for proper paint adhesion. Other plastics, such as urethanes, do not require this chemical surface treatment. Some paint manufacturers have one primer for olefin-containing plastic and a different primer for plastics that do not contain olefin. Other paint manufacturers have one primer for all types of plastics.

It is important to know if the plastic is olefin-based because olefin-containing plastic may require special surface preparation. A ***float test*** can be performed to determine whether or not a plastic contains olefin. To conduct a float test, cut a sliver from the plastic part, remove the paint, and drop the sliver into a cup of water. If the sliver floats, it contains olefin. If the sliver sinks, it does not contain olefin.

Refinishing Plastic Parts

Original Finish Plastic
Unprimed (Bare) Plastic

1. Clean part with SC155 Low VOC Cleaner.
2. Scuff sand using a white scuff pad and USP90 Liquid Scuffing Agent giving special attention to small grooves and depressions.
3. Thoroughly rinse off the scuffing agent with clean water and completely dry the surface.
4. Reclean the surface with SC155 Low VOC Plastic Cleaner.
5. Apply one full wet coat of either UPO7266 or 7227t. Then apply flexed E6H59 Color Seal, flexed E6C61 Transparent Adhesion Promoter or PSE4600/4601 Epoxy.
6. Apply basecoat with hardener (1oz per sprayable quart of UH80, UH100 or CCH690 or UH900).
7. Apply clearcoat as recommended. No flex additive is required in the following clearcoats: CC635, CC637, CC639.

Note: check primed parts for solubility by pressing a solvent saturated towel on the surface (small area) on the feature line, where the primer is thinnest and hold for 30 seconds. If soluable, remove primer and treat as unprimed plastic.

Figure 31-2. *An example of a paint manufacturer's plastic painting recommendations. (Sherwin Williams)*

Preparing and Spraying Plastic Parts

The following section outlines the procedures for preparing and painting various plastic parts. Paint manufacturer's recommendations may vary from these procedures. If so, follow the manufacturer's recommendations. See **Figure 31-2.** Surface preparation is very important for a successful paint job. Most paint problems are due to improper preparation. The biggest problem in plastic painting is poor adhesion. Poor adhesion means that the paint cannot stick to the surface of the part.

Cleaning

As with all refinishing, painting plastic demands a clean surface. Soap and warm water should be used to remove water-soluble contaminants. During vehicle manufacture, ***mold release agent*** is added to the liquid plastic to allow for easier removal of the finished part from the mold. Once the part is out of the mold, the job of the mold release agent is over. However, the mold release agent remains on the surface of the part. Mold release agent remaining on the surface of the part is a contaminant and it will prevent paint from adhering.

CAUTION

Mold release agent is water soluble. Use water and detergent to remove the release agent. Solvents will not remove this waxy, water-based agent. Only soap, water, and brushing will remove mold release agent. Grinding or sanding before cleaning will drive the release agent into the panel surface, contaminating it further, and causing adhesion problems later when the panel is painted.

A plastic cleaner should be used to remove oil-soluble contaminants, **Figure 31-3**. Avoid the use of the wax-and-grease remover used on steel. Rubbing the bumper cover may cause the buildup of static electricity. The wax-and-grease remover used on steel may ignite from a spark caused by the static electricity. Plastic cleaner will not ignite. Wiping should be in one direction only, and do not wipe over the same area twice. Plastic cleaner can be made from a 1:1 mixture of isopropyl alcohol and water.

Once the plastic surface is cleaned, do not clean it again unless additional cleaning is recommended by the paint manufacturer. The reason for only one cleaning is that the solvent may be absorbed by the plastic, causing paint problems later on. This is especially true on fiberglass or SMC, as the fibers absorb the solvent. If the cleaning, sanding, and painting are performed one after the other in a short span of time, the chance of contamination is minimized.

Sanding

After cleaning, plastic parts should be thoroughly sanded to ensure proper paint adhesion. On intricate parts, a scuff pad can be used to abrade difficult-to-reach areas. See **Figure 31-4**. Remove all the shine when sanding. Prime or paint the part within 30 minutes of sanding. SMC body lines or edges can be ruined by careless sanding. Aggressive 180-grit or coarser sandpaper can quickly erase a bodyline. Be careful when power sanding. Stay away from body lines and edges. Hand sand around these areas. Rounded off body lines, caused by careless sanding, can be repaired with body filler. Remove sanding dust by blowing off the surface and wiping it down with a tack rag.

KENT
POLYPREP AP

Figure 31-3. *A plastic cleaner should be used to prepare plastic parts.*

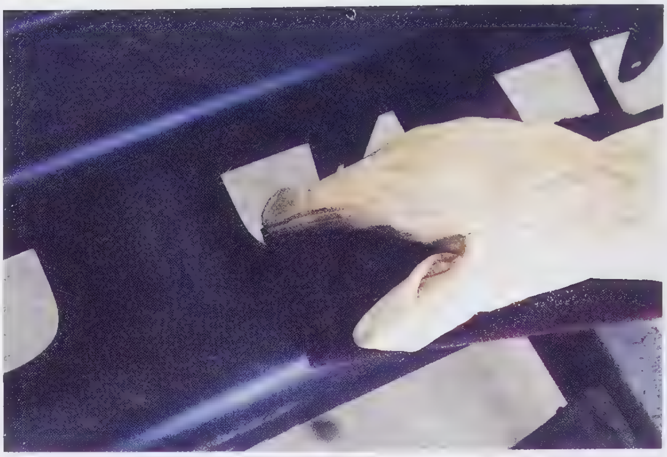


Figure 31-4. *A scuff pad is used to conform to the odd-shaped area on a plastic bumper.*

WORKING GREEN

- **Leave work clothes and shoes at the shop. Have clothes cleaned by a professional laundering service.**
- **Do not eat or drink food left in the work area because particle pollution (dust) can contaminate these items.**
- **Do not smoke in the work area because it is possible to swallow dust through hand-to-mouth contact.**

Source: U.S. EPA

Spraying Plastic Parts

Because of their shape, plastic parts may be difficult to spray. A narrow or deeply recessed portion of the part may cause difficulties. The spray gun fan must reach the area without creating a run or dry overspray. Some suggestions to follow when spraying difficult parts include:

1. Position the part so it is oriented as if it were installed on the vehicle. See **Figure 31-5**. This is especially important when spraying metallic colors. It will help the metallic paint on the part match the metallic paint on the vehicle.
2. Adjust the spray gun to a narrow fan, and set material and air pressure accordingly.
3. Spray the difficult-to-reach areas first.
4. Some areas can be reached from the back side of the part. See **Figure 31-6**.
5. After the difficult areas have been sprayed, tack off the overspray.
6. Adjust the spray gun to a wider fan, and set the material and air pressure accordingly.
7. Spray the accessible areas of the bumper, keeping the overspray to a minimum with wet coats.

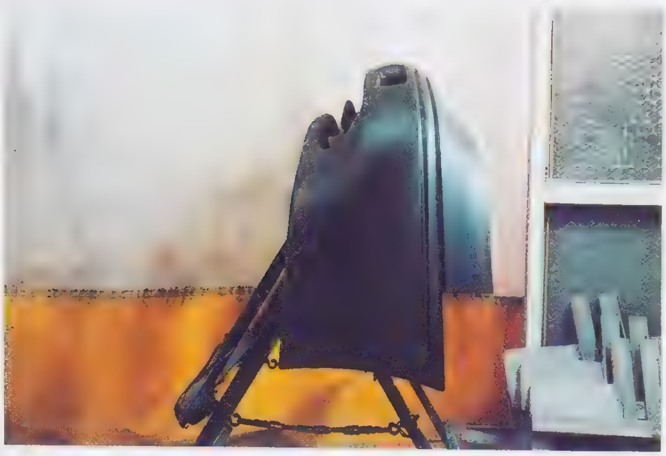


Figure 31-5. *This bumper has a deeply recessed, difficult-to-spray opening. Otherwise, it would be positioned as it would be on the vehicle.*

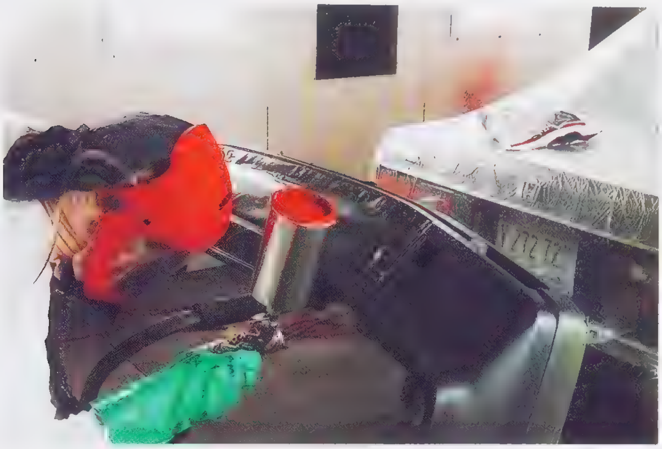


Figure 31-6. *This painter sprays a difficult-to-reach area from the back side.*

Paint manufacturers have specific procedures for painting plastics. Obtain the guidelines for the specific system being used and follow the recommendations closely.

Surface Preparation for Specific Types of Plastic

The following sections outline the surface preparation procedures for various plastics, beginning with examining the part and continuing through priming.

CAUTION

Always assume that mold release agent is present on the surface of bare plastic.

New, Bare, Non-Rigid Plastic Part

If the plastic is bare and shiny, mold release agent may be present on the surface. The presence of mold release agent on the plastic surface can cause an adhesion problem. Shops that have a baking spray booth may pre-bake the part at 140°F (60°C) for 20 minutes.

NOTE

To avoid the expense of turning on the baking system just to pre-bake a part, place the part in the spray booth while another vehicle is baking.

Pre-baking softens mold release agent on the surface of the part. Follow the procedures listed below after baking or if baking is unavailable.

1. Wash the part with soap and warm water.
2. Wipe down the surface with a plastic cleaner. Move the wiping cloth in one direction only and do not pass over the same area twice.
3. Scuff-sand the part thoroughly with 600-grit wet sandpaper. Instead of water, use a 1:1 mixture of water and isopropyl alcohol.
4. Dry the part, and wipe it down with a tack cloth.
5. Spray on the appropriate plastic primer. Olefin plastics may require the application of a special primer within 10 minutes of sanding.
6. Allow the primer to dry.
7. Spray on a two-part sealer. Some manufacturers may specify a special flexible sealer. Follow the manufacturer's recommendations.

New Primed, Non-Rigid Plastic Parts

Most plastic parts are primed by the manufacturer. A primed part will have a dull surface, not shiny and slick like a bare part. Nevertheless, the primer itself can cause a problem. For example, the primer may not adhere properly to the plastic. To check for primer adhesion, use a piece of 2" masking tape. Apply the tape to the primer and rub on the tape to make it stick. Then, quickly pull off the tape. If primer is removed with the tape, you have an adhesion problem, **Figure 31-7**. If you discover an adhesion problem, sand off all the primer and prepare the part as you would any bare plastic component.

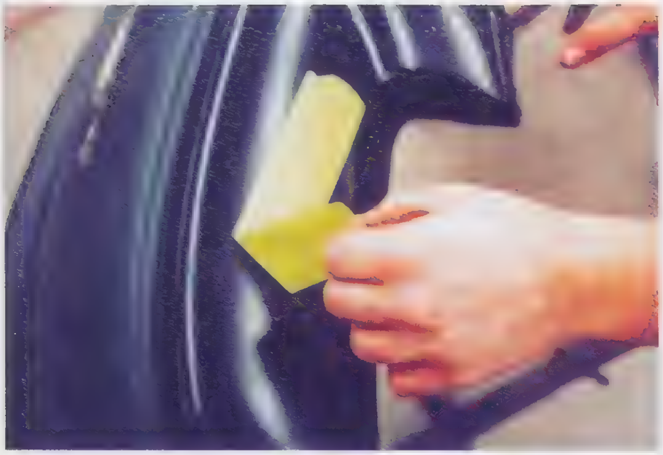


Figure 31-7. *The adhesion test is performed with 2" masking tape. Primer was not removed in this particular test, so the primer on the bumper passes the adhesion test.*

Another potential problem with primed plastic parts is lifting. To check for lifting, apply lacquer thinner to a rag and touch the rag to the primer as shown in **Figure 31-8**. If the primer is dissolved by the lacquer thinner, the primer should be removed. If this primer were sprayed with paint, the primer and paint would lift. If the primer passes both the adhesion test and the lifting test, the part can be prepped in the following manner:

1. Wash the part with soap and warm water.
2. Clean the surface with plastic cleaner.
3. Scuff sand the part with 400-grit wet sandpaper. Pay special attention to the edges and bodylines. Do not cut through the primer. Use a scuff pad on complex areas.
4. Dry off the part and wipe it down with a tack rag.
5. Spray on a two-part sealer. Some manufacturers may specify a flexible sealer with an added flex agent. Others do not require flex agent in the sealer. Always check the manufacturer's recommendations.

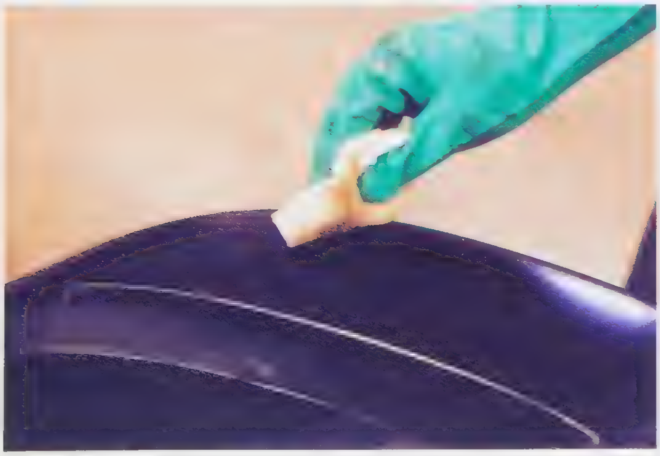


Figure 31-8. *The lifting test is performed with lacquer thinner. No primer is seen on the rag so the primer on this bumper passes the lifting test.*

Repaired Non-Rigid Plastic Parts

Improper surface preparation can lead to bull's-eyes. A ***bull's-eye*** is a visible ring around a painted and repaired area. To avoid adhesion and bull's-eye problems at the edge of a repair, some technicians apply plastic repair material over the featheredge of paint. See **Figure 31-9**. This covers the bare plastic with a layer of plastic repair material.

NOTE

Applying plastic repair material may not be allowed by all paint manufacturers.

Once the plastic repair material is block sanded, the following procedures can be performed:

1. Featheredge the surrounding paint. If a layer of plastic repair material is intended to stay over the featheredge, be careful when sanding. Do not remove it.
2. Apply a plastic primer. Olefin plastics may require a special primer.
3. Apply a flexible surfacer. Flexible surfacers are usually the same surfacers used for steel with an added flex agent.
4. Allow the flexible surfacer to cure.
5. Block sand the flexible surfacer with 320-grit dry sandpaper followed with 600-grit wet sandpaper.
6. Spray on a flexible sealer.

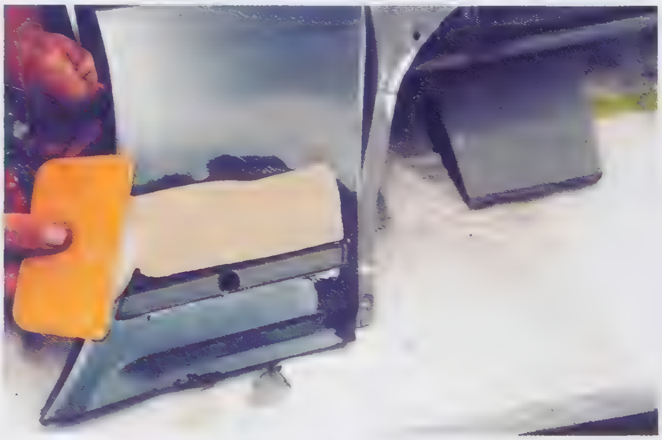


Figure 31-9. *Plastic repair material is applied over the featheredge of paint. This will prevent a bull's-eye.*

New Rigid Plastic Parts

The procedures for preparing hard plastics, such as SMC and FRP, are similar to those for preparing steel parts. Begin by washing the part with soap and water, and clean it with plastic cleaner. Next, scuff-sand the part with 400-grit sandpaper. Finally, spray on a coat of sealer. No flex agent is needed.

Repaired Rigid Plastic

The procedures for preparing repaired rigid plastic are similar to those for steel. Avoid bull's-eyes by careful featheredging and block sanding. Begin by featheredging the paint with 80-grit sandpaper. Follow with 180-grit and finally with 320-grit sandpaper. See **Figure 31-10**. After sanding, blow off the part and wipe it down with a tack rag. Apply three coats of surfacer and allow it to cure. Block sand surfacer with 320-grit dry sandpaper followed with 600-grit wet sandpaper. Finally, spray on a coat of sealer.

Painting Specific Types of Plastic

This section is divided into two parts. The first section discusses the procedures for painting flexible and semi-rigid plastics. Flexible and semi-rigid plastics can deflect without damage. The paint on these parts must be able to do the same. The second section details the method for painting rigid plastics. Rigid plastics do not deflect, so the paints for these parts do not need a flex agent.

Flexible and Semi-Rigid Plastic Parts

When spraying flexible and semi-rigid parts, the technician must determine whether a flex agent is required. Flex agent will keep the paint pliable after curing. If a flex agent is required, it is added to the clearcoat, but not to the basecoat. The basecoat is flexible enough without a flex agent. **Figure 31-11** shows a can of flex agent. A set of mixing instructions is shown in **Figure 31-12**. Always check the paint manufacturer's recommendations. If flex agent is required, be sure to use it.

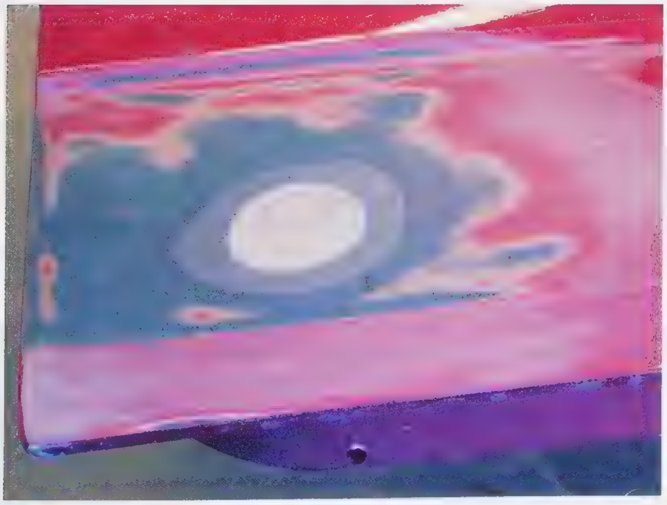


Figure 31-10. *Featheredging in SMC (sheet molded compound) is similar to featheredging steel. Expose about 1" of each paint layer.*

DU PONT
PLAS-STICK®
2K FLEX-ADDITIVE
ADITIVO FLEXIBILIZANTE 2K
AN AUTOMOTIVE PAINT PRODUCT
4150 S
ONE U.S. QUART/.946 LITER • 946 Mililitros

Figure 31-11. *This is a can of flex agent. Flex agent will allow the cured paint to flex without cracking.*

Ultra 7000 4.1 VOC Air Dry Clearcoat CC-633	
4 parts	CC-633 Ultra 7000 Clearcoat
1 part	Reducer US-1 to 6
1 part	Hardener UH-80
1 part	V6-V299 Flexible Additive

Figure 31-12. *An example of a flexible clearcoat mixing ratio. (Sherwin Williams)*

When painting a front-damaged vehicle, the bumper should be painted separately as shown in **Figure 31-13**. The bumper is placed on the stand and positioned as if it were mounted on the vehicle. This will help prevent problems with color match and metallic flake orientation. Both the front end of the vehicle and the bumper are sprayed with basecoat. The vehicle is then clearcoated in the normal manner. After clearcoating, the painter mixes the recommended amount of flex agent with the remaining clear and applies this mixture to the bumper. This would not be possible if the bumper were on the vehicle.

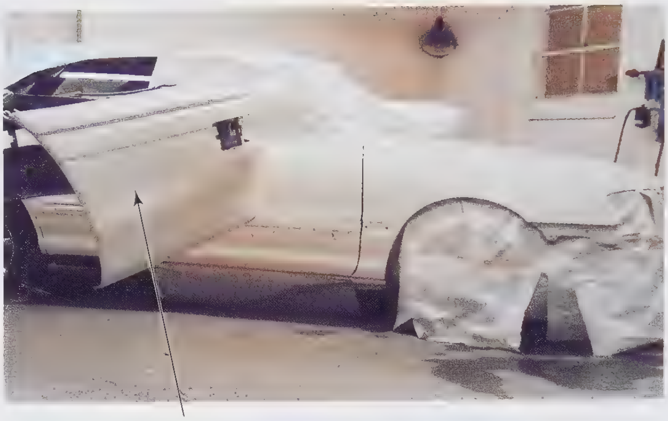


Figure 31-13. *The bumper is painted separately. This allows the bumper to be sprayed with flexible clearcoat.*

NOTE

At least one paint manufacturer suggests that flex agent is not needed if a soft or flexible plastic part is installed on the vehicle before painting.

Texture is the other consideration when repainting plastic parts. Each coat of paint fills in part of the surface texture. Too many coats of paint will make the texture smooth. Enough paint must be applied to be durable and to cover the plastic, but not so much that the desired texture is altered.

NOTE

Vinyl is painted in the same way as flexible plastic. However, refinishing of air bag modules should be avoided. Cured paint on the air bag cover may interfere with air bag deployment.

Bumpers may be two-tone: the vehicle color and either flat black, a contrasting color, or a complementary color. One way to repaint a two-tone bumper is to paint the entire bumper off the vehicle. After the bumper is reinstalled, the area to be two-toned is outlined with fine-line masking tape, and the refinish paint in this area is scuffed with a nylon pad. The rest of the bumper is masked, the area is tacked off, and color is applied. Sometimes, the two-tone area adjoins moldings on the fenders. These moldings can be cleaned, scuffed, masked, and sprayed to match the bumper.

Rigid Plastic

Rigid plastic parts can be painted on or off the vehicle. For example, an SMC door can be trimmed, and then installed on the vehicle. Afterwards, the outside of the door can be painted along with the rest of the vehicle. An FRP header panel is painted in a similar manner.

An SMC rear hatch may be easier to paint off the vehicle, due to the difficultly of reaching the upper part of the hatch. When painting a rigid part off the vehicle, position the part as if it were on the vehicle.

Custom Painting

Custom painting is the application of a unique color or color pattern to a vehicle. See **Figure 31-14**. This is not easy because completely changing the color of a vehicle is an involved process. To truly change the color of a vehicle, every portion of the vehicle—engine compartment, door openings, inside of the doors and the trunk—must be painted to match the new color of the vehicle. Some components of the inner portions can be masked off, but the best solution is to remove obstructions. For example, on the cowl/firewall, remove the brake master cylinder, heater hoses, wiper motor, speedometer cable, and any other obstructions. The obstructions can be masked, but the masked parts will interfere with spraying every surface of the cowl/firewall. Another way to change the color is to paint just the outside of the vehicle plus the inside edges of the hood, fenders, doors, and deck lid. The inside edges are painted so the different color inside the panels will not show on the outside.

A custom color can be an OEM color that was not offered for the vehicle you are painting. When selecting a color, remember that the appearance of a color in a color chip may not be the same as the final appearance. Rather than looking at small color chips to determine what color to choose, look at other vehicles to find a suitable color.

A popular custom color choice is a hue-changing color. Hue-changing colors shift in appearance depending on the viewing angle. For example, a color may change from red to blue. These colors can be applied as a tricoat: solid color base, the hue-changing intermediate coat, and a clearcoat.

Aftermarket paint manufacturers are an excellent source for custom colors, such as candy colors. A ***candy color*** is also sprayed as a tricoat. In a candy color paint job, the base color can be solid or metallic.

Figure 31-14. *This vehicle features an eye-catching custom paint job.*

The intermediate candy coat is a tinted, semitransparent paint that will either make the base color more vivid or change the appearance of the base color. With either effect, a candy color is brighter than a non-candy color.

Other aftermarket custom colors include high-metallic colors. A ***high-metallic color*** has larger-than-normal metallic flakes. The metallic is so heavy that it rapidly settles to the bottom of the paint cup during spraying. A special agitator cup may be required to spray a high-metallic paint on a siphon-type spray gun. The agitator cup keeps the metallic flake in suspension for consistent flake dispersion. High-metallic colors, because of the large amount of gray added by the metallic, tend to have less chroma (the intensity or brilliance of a color) when compared to nonmetallic colors.

There are two ways to create a new color. One way is to alter an existing color formula by adding or subtracting tints. The other way is to combine tints. The weight of each amount of tint should be recorded so the color can be reproduced later. Remember, the more tints added, the less chroma the color will have. Vibrant colors have one dominant tint and only small amounts of additional tints.

When creating a custom tricoat color, the choice of base color and pearl color is critical, as the pearl can change the color of the base. For example, a black basecoat with a red pearl coat looks black in low light and brown in bright sunlight. More coats of pearl tend to reduce the chroma of a color. If the base color is dark, mix one spray gun cup of ready-to-spray clear blender or clearcoat with one teaspoon of pearl powder. If the base color is light, mix one spray gun cup of ready-to-spray clear blender or clearcoat with two teaspoons of pearl powder. Spray test panels to determine how the basecoat and pearl coat will interact and how many pearl coats are required.

Candy Colors

Candy colors require excellent spray technique to look good. Poor application will leave light and dark bands in the color. A uniform color, with no variation, is the signature of a good candy paint job. To make the candy color uniform, a strict 75% overlap of the candy coat must be maintained. The 75% overlap is critical.

The painter must not follow bodylines when spraying. Each stroke of candy coat must be straight even if the panels are tapered. Imagine the vehicle as a square box and move the spray gun as if painting a square, flat surface. See **Figure 31-15**. Be aware of how much taper is in each panel. The vehicle can be measured before painting to determine how much taper is in each panel.

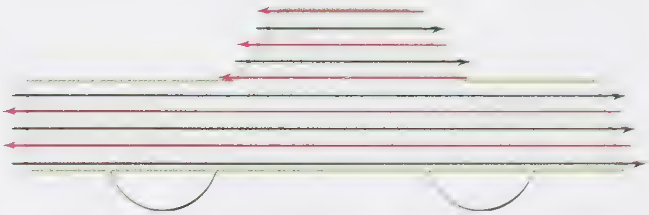


Figure 31-15. *When spraying candy colors, the painter must see the car as a rectangular box. Maintain a strict 75% overlap and keep your passes straight with no taper.*

Artistic Masking

Artistic masking describes the creative use of masking tape to form a design. There are three ways to make a design with masking tape. The first method is to draw the design with a pencil on the surface to be painted. Then, 1/4" or 1/8" fine-line masking tape is applied to the pencil line. Fine-line masking tape is used because it will not allow paint to creep underneath, and it will make a sharp, defined edge. The second way is to project a pattern onto a panel. The pattern can be an image from an overhead projector, a piece of flexible plastic, or a stiff paper cutout. Masking tape application follows the pattern. The final method is the freehand method. The freehand method has the technician laying down masking tape to form the design on the panel. The freehand method requires the most skill.

Airbrush Technique

An airbrush can be adjusted to spray a 1" or smaller fan. Some airbrushes can be set to spray a pencil-thin line. Airbrushing can follow a pattern, such as an outline projected on the panel, or can be freehand. Because the fluid tip is so small, an airbrush can atomize paint finer than a normal size spray gun allowing for a wide variety of effects.

Highlighting

Spraying a lighter accent color immediately adjacent to a darker color is a technique called highlighting. ***Highlighting*** creates the illusion of three dimensions on a flat surface. Use an airbrush set to a narrow fan. If the fan is narrow enough, no overspray will adhere to the adjacent paint, and masking of the dark color is not required. If the fan must be set larger, the adjacent paint can be masked with a cardboard cutout. To avoid smearing, allow the first color to dry before placing cardboard over it.

Shading

Shading also creates the illusion of three dimensions on a flat surface. In shading, a darker color accents a lighter color. The lighter color is applied first and the darker shading is sprayed around the lighter color. As with highlighting, the first color may need to be masked. See **Figure 31-16**.

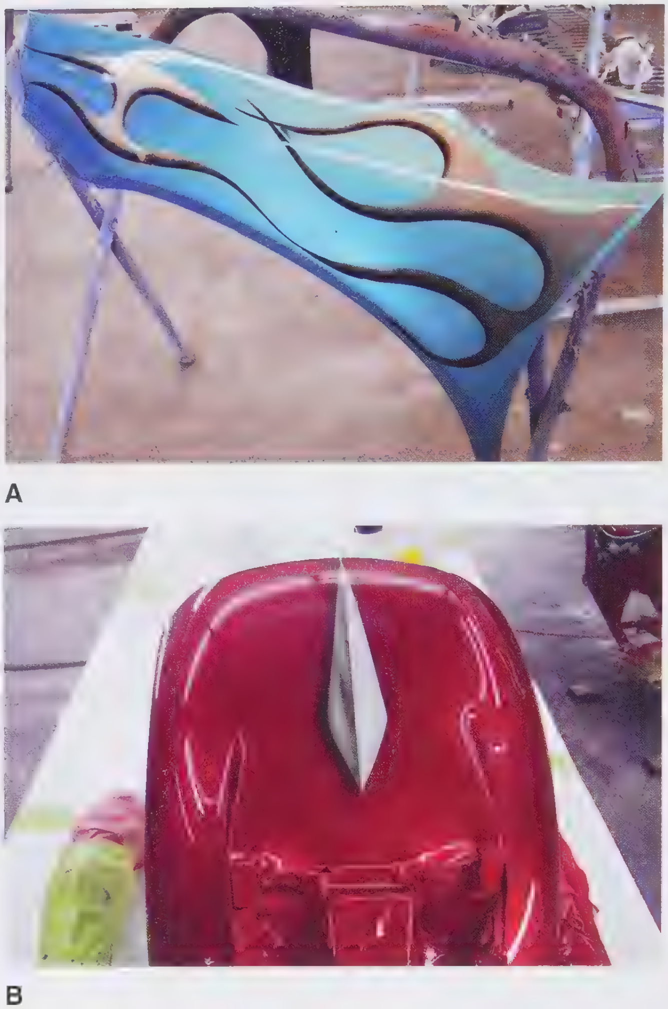


Figure 31-16. *A—Shading gives these shapes depth. B—Shading and highlighting create the illusion of three dimensions.*

Fading

Fading is a custom painting technique where one color subtly changes into another color. Any two colors can be faded together, but the most popular effect is to use adjacent colors on the color wheel when fading. For example, red can fade into orange and orange fade into yellow. One method of fading is simple: apply one color and then apply the other color. When applying the second color, arc the spray gun so the paint gradually tapers. See **Figure 31-17**.

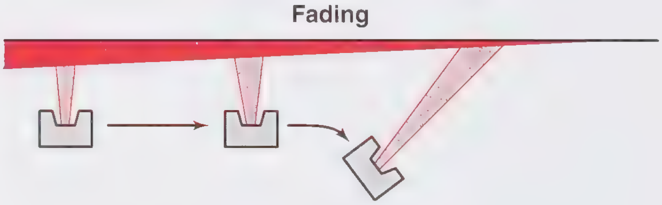


Figure 31-17. *Fanning the spray gun produces a tapered paint edge.*

This tapering can also be achieved through dusting. When dusting, paint is not overreduced. Proper atomization is critical when fading. If the paint is not properly atomized, the droplets will be large and noticeable, and the fade effect will be diminished. An airbrush has such a small fluid tip that it can atomize paint droplets small enough to "pull off" the fade effect. Dusting with a full-size spray gun may create paint droplets that are too big. Overreducing the paint will diminish the size of the droplets and enhance the fade effect. This is a sound technique, but remember that overreduced paint runs easily.

Another way to make a fade is to spray both colors at the same time. An effective method is to use two spray guns, each loaded with a different color of shaded paint. Shaded paint is paint that has been mixed one part paint, one part clear binder, and the required amount of reducer. Clear binder is a mixing tint without pigment. Shaded paint, the combination of color and clear binder, makes a low-strength color. The two shaded colors are sprayed at each other using the arc technique described above.

Stenciling

Stenciling is a painting technique similar to masking in that paint is applied to one area but not to an adjacent area. Stenciling can be as simple as a cardboard cutout, or as complex as a reusable plastic stencil, or even a computer-generated appliqué. In most stenciling, a color is sprayed and allowed to cure. The stencil masks a portion of the panel. When a second color is sprayed over the stencil, a design is formed.

With a cardboard cutout, the design is drawn on cardboard and the cardboard is trimmed. The cutout is held slightly above the surface to be painted. For a defined edge, the airbrush is aimed so the middle of the fan, where the maximum amount of paint is, hits the edge of the cardboard. For a more diffused, less defined edge, the fan is aimed beyond the edge of the cardboard so the tapered portion of the fan, where there is less paint, contacts the cutout. Different colors can be added. Hold the cutout in the same position when applying different colors. Moving the cutout away from the surface will lose the edge. Another type of simple stencil is a plastic mesh, metal screen, or cloth lace. These are placed on the panel and the paint is applied over the stencil with an airbrush or spray gun.

There are many varieties of reusable plastic stencils available. As with cardboard cutouts, hold the stencil on the surface and apply the paint with an airbrush. The stencil will help apply an outline. The outline can be filled in with different colors to complete the design. **Figure 31-18** shows a reusable stencil being used to create a skull design.

The most complex type of stencil is designed on a computer. An image can be drawn on the computer or scanned into the computer. A special computer program will print the design on contact paper. The contact paper is cut around the design to make the stencil. The stencil is applied to the surface and the cutout area is painted.

There are two rules for stenciling. The stencils must conform to the panel contour, and the stencils should not allow paint to creep under the edge. A stencil must be very flexible to conform to the shape of a highly crowned panel. Unless there is some type of adhesive to fix it in place, the stencil will not adhere to the side of a vehicle. The stencil must be heavy enough to lay on the surface to keep sprayed paint out and stay in place as the air pressure from the spray gun blows over it.

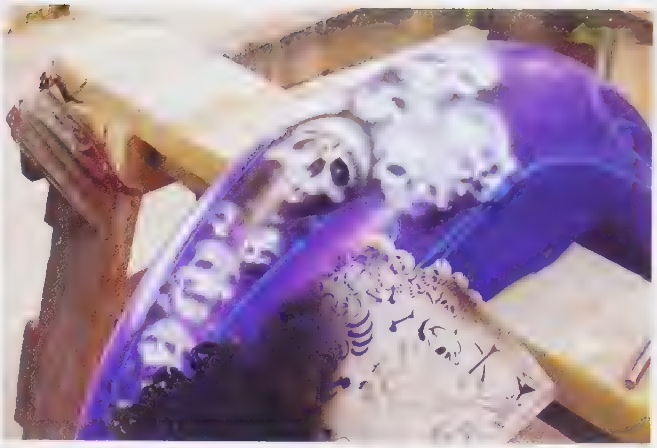


Figure 31-18. *These skulls on a motorcycle fender were made with a reusable stencil and an airbrush.*

Masking

Artistic masking outlines a pattern. There are two types of artistic masking: positive and negative. In positive masking, a color is sprayed and then cured; masking tape is applied over the color to protect the color from overspray. In negative masking, the outline of a pattern is formed with masking tape and the paint is applied inside the border of the tape to make the design. **Figure 31-19** shows negative masking application on a hood.

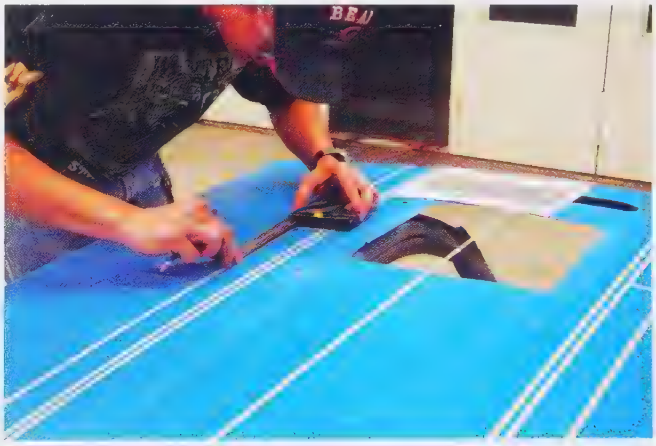


Figure 31-19. *This technician is laying out a negative masking pattern on a vintage Mustang Mach 1 hood.*

Positive and negative masking can be used to make a stripe. If a vehicle will be custom painted dark blue with an orange stripe, one way to make the stripe is by positive masking. Orange basecoat and clearcoat are sprayed where the stripe will be. Once the paint cures, the orange color is masked to form the stripe. Masking tape defines the stripe. The orange paint that is not part of the stripe is scuffed and the vehicle is painted dark blue. The positive masking protects the orange stripe underneath. To negatively mask the stripe, the vehicle is painted with dark blue basecoat and clearcoat. After the paint cures, the outline of the stripe is masked off. For example, for a 3/4" wide stripe, apply 3/4" masking tape to the panel. Masking tape is a uniform width and forms the border of the stripe. Next apply fine-line masking tape to the edges of the 3/4" masking tape. Remove the 3/4" masking tape. The fine-line tape forms the edge of the stripe. Scuff the paint inside the border of the tape before applying the orange basecoat and clearcoat.

Ghosting

When ***ghosting***, a design is masked off and the color applied is only slightly different from the background color. The difference between colors is not noticeable from every angle. Only at the proper angle is the subtle color difference, and the design, visible. **Figure 31-20** shows a ghosted design.

Marbleizing

When ***marbleizing***, a panel is first painted with basecoat and clearcoat. After the paint is allowed to cure, the clearcoat is scuffed and the panel is cleaned. A contrasting color of basecoat is sprayed over the panel. While the basecoat is still wet, clear plastic food wrap is placed on the wet paint. After waiting from ten seconds to one minute, the plastic wrap is carefully pulled off the panel. Some of the wet paint will come off when the plastic wrap is removed, forming a unique and unpredictable paint pattern that resembles the random veins of color found in marble stone. The panel is then clearcoated.

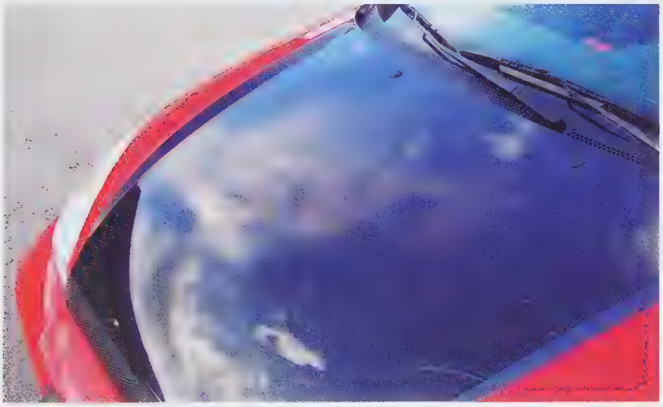


Figure 31-20. *The ghosted SVT is only visible when viewed at an angle.*

Flames

To spray flames on existing paint, scuff the clearcoat. On new paint, spray the panel and apply one coat of clear, allow the clear to cure, and then scuff. The paint on the panel is called the background paint. Lay out a pattern for the flames with 1/4" masking tape. Good flames taper gracefully, always wide to narrow. See **Figure 31-21**. **Figure 31-21A** shows a panel that was properly masked to make attractive flames. **Figure 31-21B** shows flames that were not well masked.

The next step is to mask off all portions of the background paint that will not be painted. Spray the flame colors. One classic color combination is white, fading to yellow, fading to orange, fading to red. The red is only used at the tips of the flames.

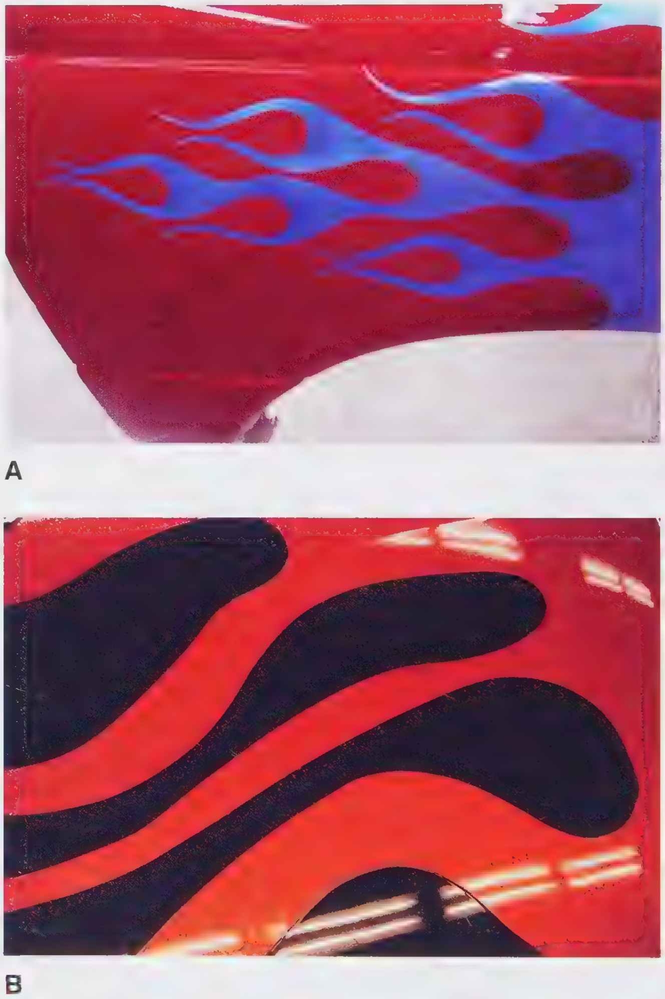


Figure 31-21. *A—The flames on this panel are graceful because they taper from wide to narrow. B—These flames look awkward.*

Ghost flames are sprayed in a color that is either very similar to the background paint or a shaded color. The ghost flames are subtle. They are visible only from one angle.

Realistic flames are made by stenciling with a cardboard cutout. **Figure 31-22** shows realistic flames. One cutout should have the curve at the base of the flame and a second cutout should feature the edge of the flame. The realistic flames are made by positioning and repositioning the stencil and fading the colors together.

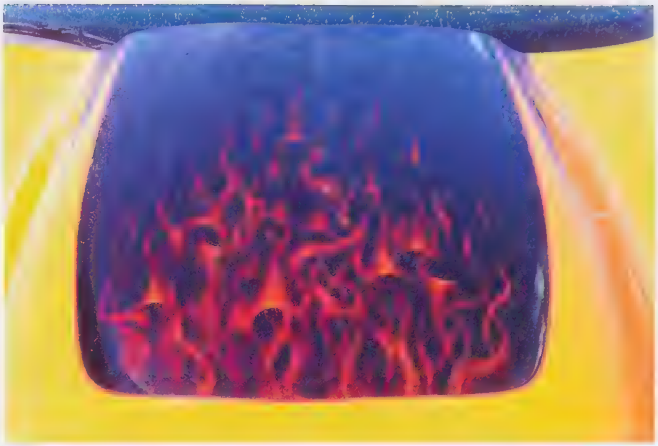


Figure 31-22. *Realistic flames are made with movable stencils, an airbrush, and a keen sense of artistry.*

Simulated Chrome

Simulated chrome is a painting technique that makes a flat panel look like a three-dimensional chrome bumper. Simulated chrome is made by first spraying a bright silver basecoat, followed with clearcoat. The clearcoat is allowed to cure, and then is scuffed. The three-dimensional appearance is made with an airbrush by shading the bright silver with a darker silver. A stencil can be used to mask a portion of the bright silver paint to form the shape of a bumper. For even more authenticity, the lower portion of the bumper design is dusted with earth-tone colors, green or brown, while the upper portion of the design is dusted with blue, to represent the sky. The entire panel is sprayed with clearcoat. See **Figure 31-23** for an example of simulated chrome.

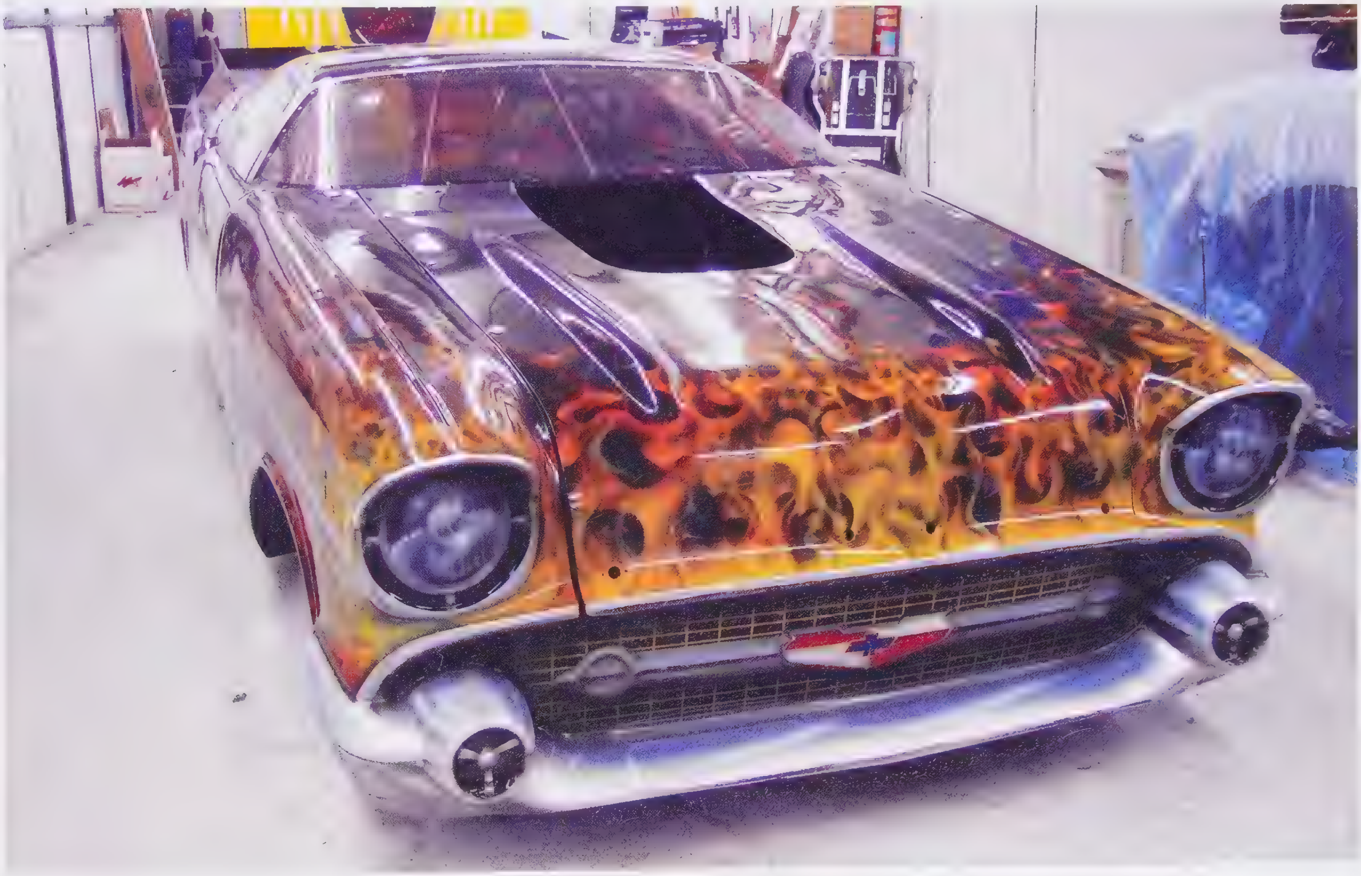


Figure 31-23. *The bumper on this vehicle was painted to look like chrome. Shading and fading create the awesome 3-D effect.*

Simulated Wood Grain

Simulated wood grain starts with tan basecoat followed with clearcoat. The cured and scuffed clearcoat is sprayed with a pattern of brown basecoat to represent the growth rings in a tree trunk. A cardboard cutout stencil can be used to form the edge of the rings. The rings are both highlighted and shaded for a three-dimensional effect. The design can also be painted by hand with an artist's brush. **Figure 31-24** shows a wood grain pattern.

Summary

- Obtain and follow the manufacturer's recommendations for painting plastic.
- Olefin-containing plastics require an adhesion promoter.
- Mold release agent may be present wherever bare plastic is exposed.
- Test-fit bumper covers before painting.
- The float test will show if a plastic contains olefin.
- Always clean plastic parts with soap and warm water followed with plastic cleaner.
- Thoroughly sand all plastic parts prior to painting.
- Check for primer adhesion and lifting on primed, new plastic parts.
- Spray the difficult-to-reach parts of a bumper first.
- If a part is painted off the vehicle, orient the part as if it were on the vehicle.
- Add flex agent to surfacer, sealer, and clearcoat if recommended by the paint manufacturer.
- Do not paint air bag module covers.
- Rigid plastic parts can be painted on or off the vehicle.
- Completely changing the color of a vehicle is an involved process.
- Custom colors can be created by combining tints to create a new color.
- Masking tape can be used creatively to form a unique design.
- A wide variety of techniques such as shading, fading, stenciling, and marbleizing can be used to customize the appearance of a vehicle.

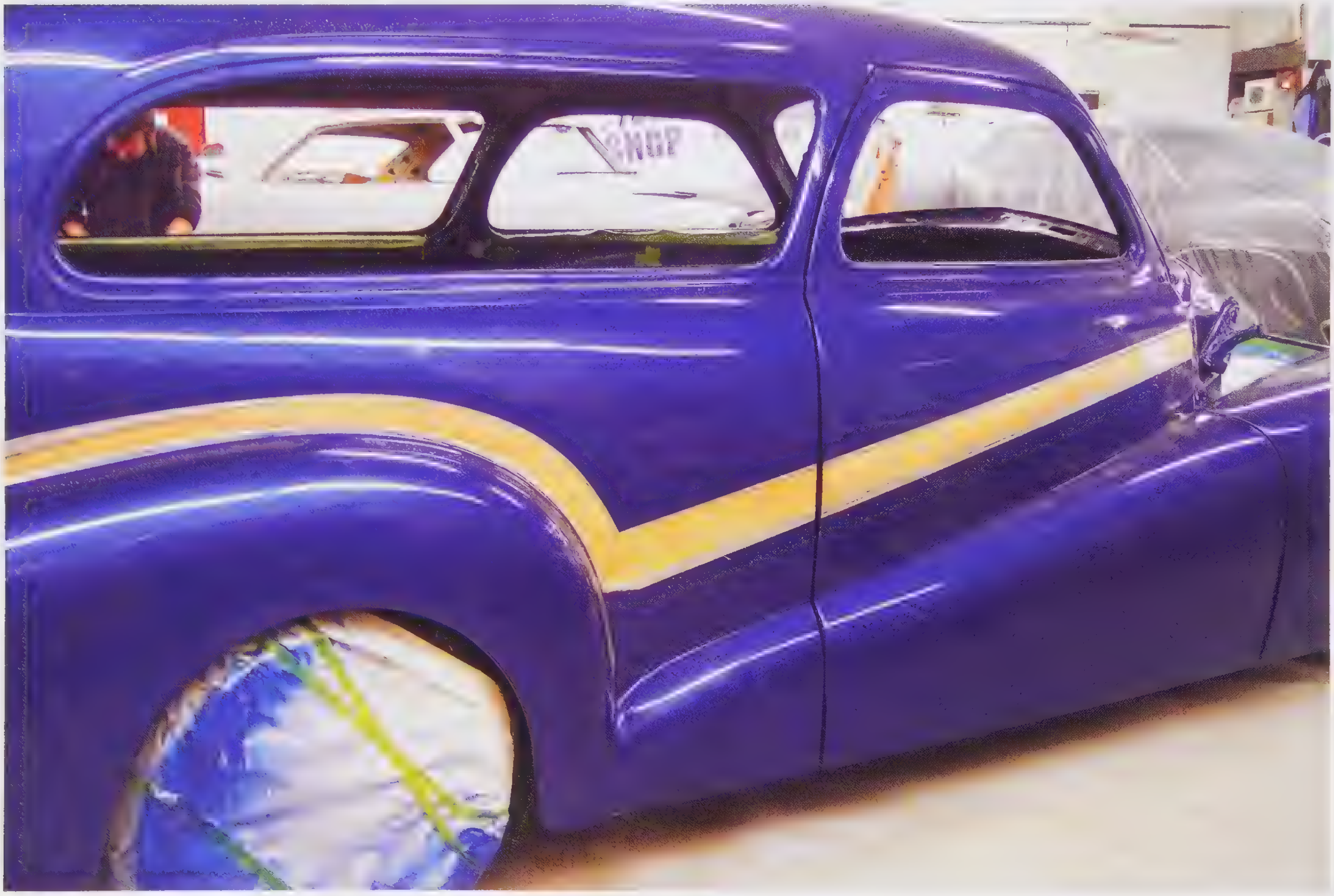


Figure 31-24. *This wood grain pattern was painted on. Tan and brown basecoat, stencils, highlighting, and shading are skillfully combined to simulate wood trim.*

Review Questions

Please do not write in this textbook. Place your answer on a separate sheet of paper.

1. The trend in the automobile industry is to use more plastic parts because they lower costs, they are easier to recycle, and their lighter weight improves fuel economy. True or False?
2. Poor ______ means that the paint does not stick to the surface.
3. ______ allows cured paint to bend without cracking.
4. Flex agent is added to the basecoat. True or False?
5. Flex agent may be required in the surfacer and in the ______.
6. The float test is used to determine if a plastic contains urethane. True or False?
7. Explain why an adhesion promoter is needed for olefin plastics.
8. Explain the purpose of mold release agent.
9. Plastic cleaner can be made from a 1:1 mixture of ______.
10. The presence of water-based mold release agent on the surface of a plastic part will cause paint adhesion problems. So, the part must first be brushed cleaned with ______.
11. Rubbing a plastic part with a wiping cloth may cause the buildup of ______.
12. Pre-baking a new plastic part at 140°F (60°C) for 20 minutes will soften the mold release agent and make it easier to remove. True or False?
13. If plastic is sanded and the bare surface is cleaned with solvent, the solvent may be absorbed by the plastic, therefore the surface should be cleaned only once with solvent. True or False?
14. List the steps in prepping an unprimed, new plastic part.
15. A primed, new plastic part is checked with lacquer thinner to see if the primer ______.
16. The adhesion of primer on a new part is checked with 2" masking tape. The tape is pressed down, then pulled off to determine if the primer is adhering to the part. True or False?
17. The visible ring around a painted and repaired area is called a(n) ______.
18. An irregularly shaped or difficult part can be sanded with a(n) ______ pad.
19. Candy colors require expert spray technique. Poor application will leave bands of light and dark in the color. What percentage of overlap must be strictly maintained when spraying candy colors?
20. An airbrush can be adjusted to spray a fan 1" or smaller. True or False?

ASE-Type Questions

1. A float test is made; the plastic part floats. Technician A says the part is urethane. Technician B says the part contains olefin. Who is right?
   (A) A only
   (B) B only
   (C) Both A and B
   (D) Neither A nor B
2. All of the following plastics can be repainted EXCEPT:
   (A) Urethane
   (B) SMC
   (C) TEO
   (D) E-EMA
3. Technician A says that flex agent must be added to basecoat. Technician B says that flex agent may need to be added to clearcoat. Who is right?
   (A) A only
   (B) B only
   (C) Both A and B
   (D) Neither A nor B
4. The adhesion of the the primer on a primed new plastic part is checked with ______.
   (A) masking tape
   (B) lacquer thinner
   (C) sanding
   (D) wax-and-grease remover
5. A new plastic part has a dull finish. Technician A says that it is a primed part. Technician B says that it is an unprimed part. Who is right?
   (A) A only
   (B) B only
   (C) Both A and B
   (D) Neither A nor B
6. Technician A wants to test-fit a bumper cover before painting. Technician B says that if the bumper reinforcement is difficult to install, the bumper should be assembled before painting. Who is right?
   (A) A only
   (B) B only
   (C) Both A and B
   (D) Neither A nor B
7. Plastic primer is also called ______.
   (A) thinner
   (B) reducer
   (C) adhesion promoter
   (D) filler
8. The first step in prepping a primed, new plastic part is ______.
   (A) sand with 400-grit sandpaper
   (B) clean with wax-and-grease remover
   (C) sand with 80-grit sandpaper
   (D) wash with soap and warm water

9. A new hard plastic part is to be painted. Technician A wants to clean the part with a plastic cleaner. Technician B wants to scuff-sand with 180-grit sandpaper. Who is right?
   (A) A only.
   (B) B only.
   (C) Both A and B.
   (D) Neither A nor B.
10. Technician A uses a flex agent when painting SMC. Technician B uses a plastic cleaner to remove oil-soluble contaminants before painting SMC. Who is right?
   (A) A only.
   (B) B only.
   (C) Both A and B.
   (D) Neither A nor B.
11. All of the following may require flex agent EXCEPT:
   (A) clearcoat.
   (B) surface.
   (C) basecoat.
   (D) sealer.
12. A primed plastic part fails the primer adhesion test. Technician A wants to remove all the primer. Technician B wants to featheredge the primer around the area where the primer was pulled off and scuff the remaining primer. Who is right?
   (A) A only.
   (B) B only.
   (C) Both A and B.
   (D) Neither A nor B.
13. A flexible bumper will be painted off the vehicle using a metallic paint. Technician A says that the orientation is not important. Technician B says that the part should be orientated as if it were on the vehicle. Who is right?
   (A) A only.
   (B) B only.
   (C) Both A and B.
   (D) Neither A nor B.
14. A bull's-eye is a ______.
   (A) visible ring
   (B) high spot
   (C) scratch
   (D) gouge
15. A mold release agent is present on the surface of a plastic part. Technician A wants to bake it off. Technician B wants to clean it off with soap and water. Who is right?
   (A) A only.
   (B) B only.
   (C) Both A and B.
   (D) Neither A nor B.

Chapter 32

Detailing

Objectives

After studying this chapter, you will be able to:

- Identify and remove paint defects, such as runs, dirt, orange peel, single-stage fade, scratches, and acid rain damage.
- Explain how to use a buffer for compounding, polishing, and glazing.
- Describe the procedure for installing stripe tape and moldings.
- Explain how to paint stripes.
- Demonstrate the color sanding process (both dry and wet).
- Describe the procedures for installing decals.
- Detail a vehicle, clean up overspray, and remove oxidation.
- Describe the paintless dent repair process.

Technical Terms

acid rain
buffing window
burns
color sanding
compound
compounding
glaze
orange peel
paintless dent repair
polish
polishing
pull/push method
push method
rub through

Introduction

The difference between a good paint job and a great paint job is often determined by the level of detailing. This chapter explains the many diverse topics that, when grouped together, are known as detailing. Detailing is done at the end of the painting process, before the vehicle is delivered to the customer.

Detailing can also be a stand-alone process. Specialized detail shops will spend an entire day meticulously cleaning and shining their clients' vehicles. Some collision shops have a detailing department that cleans up repaired vehicles and details customers' cars.

Color sanding and buffing are the most important aspects of the paint detailing process. These procedures are done to remove surface defects in paint. Additional topics covered in this chapter include paintless dent repair; stripe, molding, and decal installation; and vehicle cleanup.

Color Sanding

Sanding a painted surface before buffing is called ***color sanding***. Color sanding will reduce buffing time by removing visible surface defects, such as orange peel and dirt particles, from the clearcoat.

NOTE

Color sanding cannot remove defects that are under the paint surface, such as lifting, sand scratches, dirt particles in the basecoat, or fish eyes.

There are two concerns when color sanding. First, there is only so much paint on the vehicle's surface. Aggressive color sanding can *easily* remove too much paint. For example, color sanding will remove orange peel by abrading away the high spots until the surface is smooth and level. The problem is that paint film is very thin, typically 3–5 mils of basecoat/clearcoat on top of the primer coat. Additionally, clearcoat must be at least 2 mils thick to protect the underlying basecoat from the harmful effects of the sun's UV rays. So, as you can see, there is not much paint thickness, or margin for error, when color sanding. Also, paint is at its thinnest on door and hood edges, the driprail, and along bodylines. Avoid edges and bodylines when sanding, as it is easy to remove too much paint in these critical areas.

The second concern is that any sand scratches made when color sanding must be removed. Buffing can easily remove 2000-grit sandpaper scratches. However, scratches from 600- or 1000-grit sandpaper are difficult to buff out. Therefore, color sanding should be done in steps. In the first step, you want to remove the defect, so match the sandpaper to the job. At this stage, 1000–1500-grit sandpaper is considered coarse. Then, use increasingly finer grits of sandpaper until the defect is removed. For example, a clearcoat with dirt or excessive orange peel should first be color sanded with 1500-grit sandpaper. This is followed by more color sanding with 2000-grit sandpaper. The coarse sandpaper cuts quickly and removes the defect, while the fine sandpaper removes the scratches made by the coarse sandpaper. Sand only enough to remove the defect.

Always start with the least aggressive sandpaper that will do the job. If defects cannot be removed with fine sandpaper, switch to a more aggressive paper. Color sanding can be performed wet or dry. Wet color sanding is shown in **Figure 32-1**. To wet color sand, first soften the sandpaper by soaking it in water. When hand sanding, use a sanding pad to prevent making finger grooves in the surface. Make small circles, rather than long strokes, and always keep the surface wet. Check your progress periodically by wiping the panel dry with a squeegee.

A jitterbug sander fitted with a water line can be used for power wet sanding. A water line supplies a constant stream of water to the work surface. See **Figure 32-2**. Power dry sanding is done with a dual action sander, as shown in **Figure 32-3**. When using this tool, always keep the sander's pad flat. Do not allow an edge to dig in. Stay in flat or low-crown areas. Avoid panel edges, contours, and bodylines.

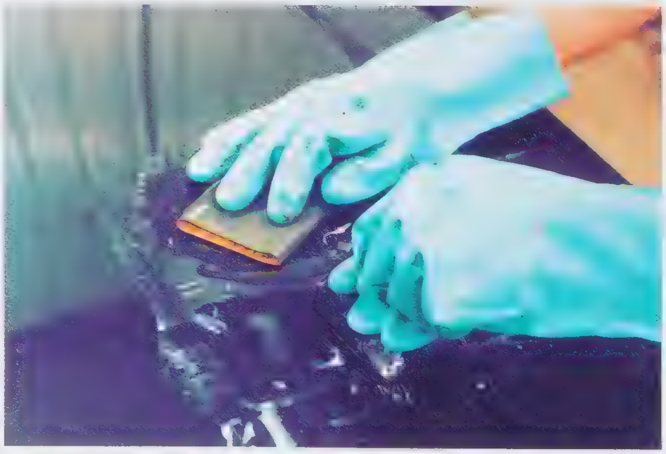


Figure 32-1. *Wet color sanding removes surface defects prior to buffing.*

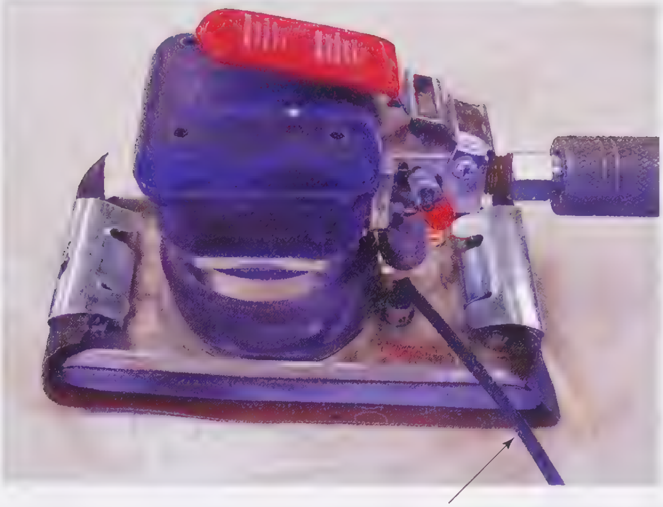


Figure 32-2. *Power wet sanding is faster than hand wet sanding. Note the water line attached to this jitterbug sander.*

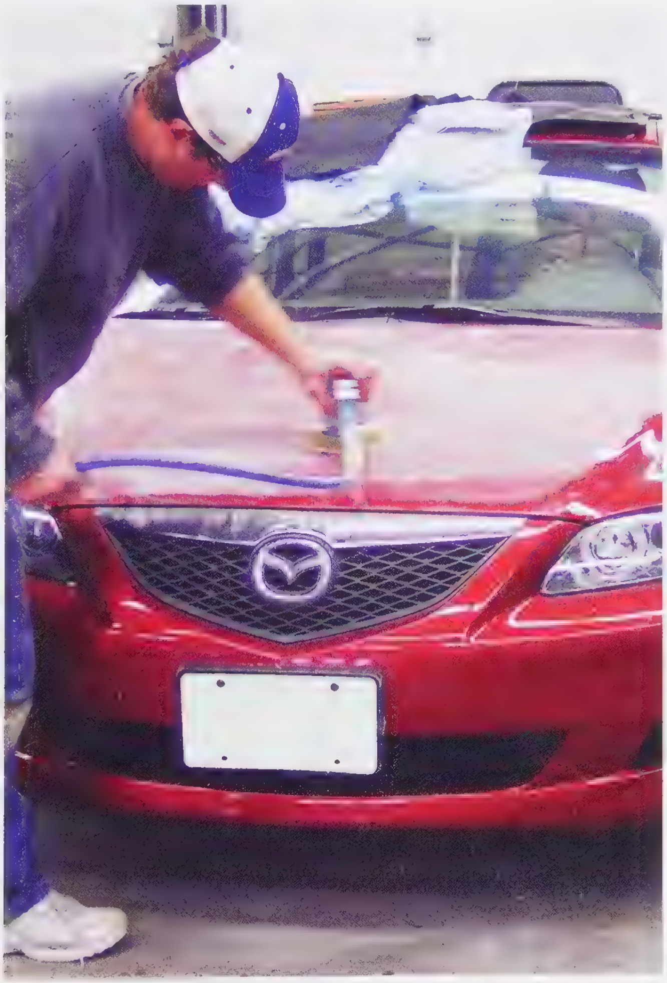


Figure 32-3. *The DA is held flat when power dry sanding.*

Buffing

Buffing will remove paint defects, such as dirt; level a bumpy, textured surface to make it smooth; and bring the shine back to a faded finish. Buffing uses abrasive materials to cut away a very thin layer of paint and expose a smooth, unblemished surface. The abrasive material can be a ***compound*** or a ***polish***. The abrasives in a compound are coarser than those in a polish. Therefore, a compound removes more paint than a polish.

Compounds and polishes are graded by the coarseness of the abrasive they contain. There are several different grades available. An aggressive compound is very coarse and will leave tiny scratches, called swirls, in the paint. A compound, depending on how coarse it is, can remove scratches left by 1200-grit or finer sandpaper used in color sanding. A polish can remove scratches left by 2000-grit or finer sandpaper, as well as scratches left by more aggressive compounds.

Buffing can be done by hand, but in a body shop an air-powered or electric buffer is used. The buffer is fitted with a pad made of either wool or foam. Some pads are designed for a coarse, aggressive cut. Other pads are designed to be less aggressive. As with coarse abrasives, a coarse pad cuts faster and removes more paint than a less aggressive pad.

Wool pads and foam pads are used in the body shop. Wool pads, either natural wool or synthetic, are the most aggressive, and there is always a danger of creating swirl marks, which must be removed by polishing. Some wool pads are made specifically for heavy cutting or compounding, while others use softer wool for fine cutting and polishing.

The other kind of buffing pad is made of foam. Foam pads run cooler than wool pads, but poor buffing technique and high buffer speeds will always result in undesirable results. Foam pads are available for applications ranging from cutting and heavy compounding, to polishing, to ultra-soft finishing.

Compounding involves the use of an aggressive pad and a coarse abrasive (compound) to quickly remove paint defects such as sand scratches. ***Polishing*** is a less aggressive buffing process intended to remove swirl marks made by compounding. Polishing involves the use of a less aggressive pad and a relatively fine abrasive (polish).

NOTE

Technicians prefer wool pads for compounding and foam pads for polishing. However, foam compounding pads and wool polishing pads are available. Wool pads should not be used on clearcoat, but there are synthetic wool pads.

There are two problems to avoid when buffing, ***burns*** and ***rub through***. A spinning pad generates heat through friction as it contacts the paint surface. Excessive heat concentrated in a small area can cause the paint to melt or burn. See **Figure 32-4**. If clearcoat is overheated, it will become very soft and then burn. As long as you keep the buffer moving across the surface and there is compound or polish on the pad, burns are unlikely. However, excessive hand pressure on the buffer with a dry pad is a recipe for trouble. In a burn, the scorched clearcoat separates from the basecoat and the basecoat separates from the undercoat. The separation may show up as blisters in the paint.

Like color sanding, buffing cuts away a thin layer of paint surface. A rub through results when all the clearcoat or paint is removed, exposing the basecoat or undercoat, **Figure 32-5**. Rub through is most common on edges and bodylines. In these two locations, where the paint layer is thinnest, the spinning buffer pad can remove all the topcoat in an instant. Prevent rub through by avoiding panel edges, high crown ridges, and bodylines while machine buffing. Always keep the buffer moving across the panel; do not dwell in one spot.

Buffing technique is a balance of hand pressure on the buffer, buffer travel direction and speed, and pad rotation speed. Apply enough hand pressure on the buffer to keep it from skating across the surface. Increasing downward hand pressure will slow pad rotation speed while making the compound or polish cut more aggressively.

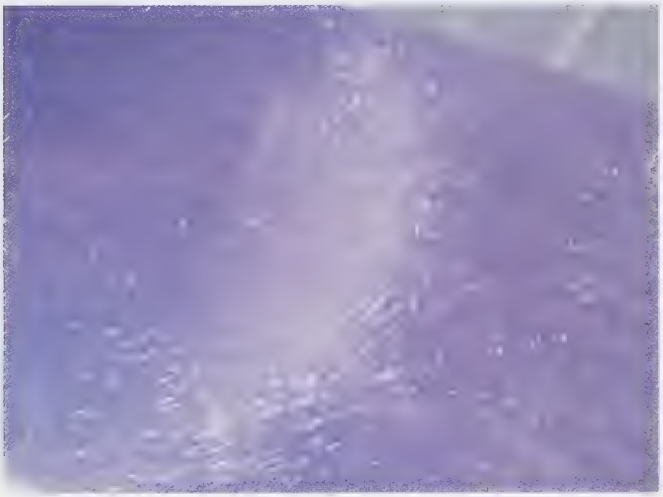


Figure 32-4. *This is a burn. It is caused by friction between the spinning buffer pad and the paint surface. You can actually see blisters in the paint. As long as there is compound or polish on the pad, and you keep the buffer moving across the surface, burns can be avoided.*

Figure 32-5. *Buffing too long in one location removes all the paint and exposes the undercoat. This is called rub through. It is common on edges, high crown ridges, and bodylines.*

Move the buffer over flat panels such as hoods or deck lids in the pattern shown in **Figure 32-6A**. The buffer must contact all the paint on the surface except the edges. Once the entire panel has been buffed, closely examine the paint for remaining surface defects. Some technicians will compound/polish an edge by hand before buffing.

Buffing a roof may require the use of a stand or a walkway. Even if you can reach the roof of a vehicle while standing on the floor, it may be difficult to exert enough downward pressure to buff effectively. A stand or a walkway positions the technician's upper body above the roof, allowing sufficient pressure to be exerted on the buffer.

Buffing a side panel, such as a door, quarter panel, or fender, is shown in **Figures 32-6 B** and **C**. Hold the buffer upright to buff the upper portions of a panel. Hold the buffer upside down to buff the lower portions of the panel. Move the buffer in long back-and-forth strokes. Be sure to avoid the panel edges, bodylines, and adjacent parts or panels. **Figure 32-6D** shows how to buff a high-crown area around a wheel opening. Use just the outer edge of the pad. Do not jam the end of the buffing pad into the panel, as this can damage paint. Buffing pads can flex slightly to conform to reverse crown, but the end of the pad should have only light contact with paint.

The buffer travel speed should be about 1' every ten seconds. Keep the pad nearly flat against the panel. Tilting the pad too much will concentrate the buffing action and increase the likelihood of a burn or rub through. Use a 50% overlap. Continue buffing until all surface defects and dullness from color sanding are removed. As the compound is buffed into the paint, the abrasive in the compound will break down into finer particles and lose the ability to cut. Additional compound may have to be added to the pad.

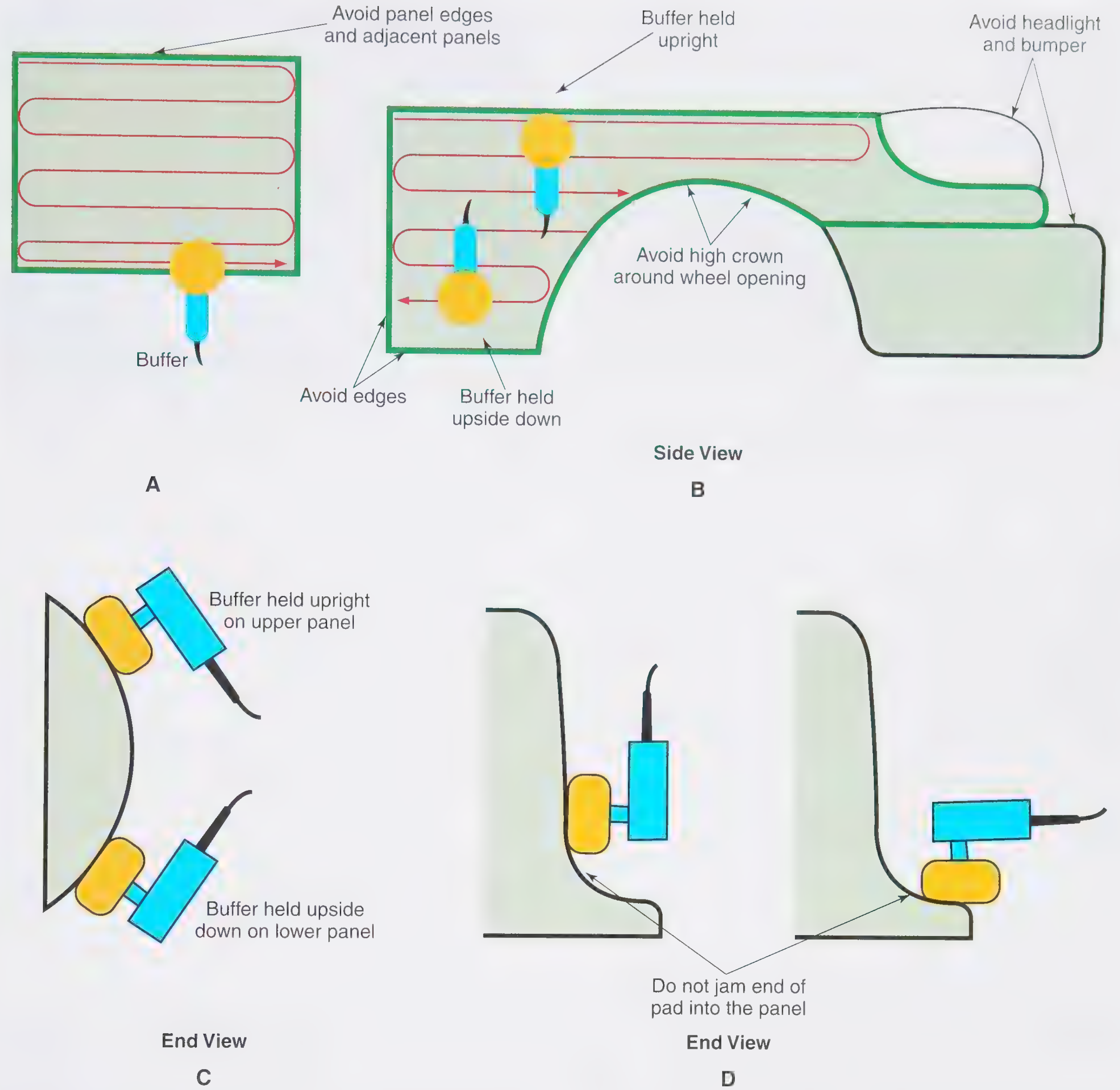

Avoid panel edges and adjacent panels
Buffer
A
Buffer held upright
Avoid headlight and bumper
Avoid high crown around wheel opening
Avoid edges
Buffer held upside down
Side View
B
Buffer held upright on upper panel
Buffer held upside down on lower panel
End View
C
Do not jam end of pad into the panel
End View
D

Figure 32-6. *A—Use long back-and-forth strokes to buff a flat panel. B—Avoid adjacent panels and edges when buffing a side panel. C—The buffer is held upright and upside down to buff a side panel. D—Carefully buff the high-crown area around a wheel opening with just the outer edge of the buffing pad.*

Some electric buffers have a speed adjustment wheel, allowing you to set pad rotation speed. See **Figure 32-7**. To buff clearcoat or single-stage topcoat, select a speed of about 1500 rpm. Apply about ten drops of compound or polish to the pad to buff a 1 sq ft area. Before turning on the buffer, use the pad to spread the material around the work area.

Buffing compound/polish is placed on the outside edge of orbital buffers or in an "X" pattern on rotary buffers. In some cases, compound is applied to the panel and spread around the work surface with the buffing pad before turning on the buffer.

Start the buffer with the pad in full contact with the panel. Do not turn on the buffer with the pad in the air, as it will sling compound all over.

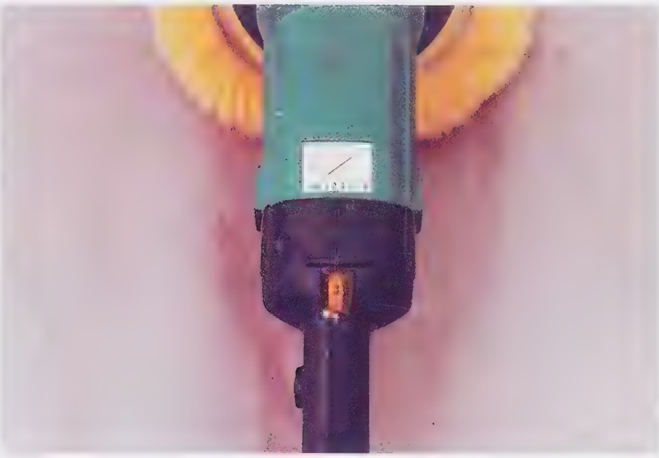


Figure 32-7. *The pad rotation speed is adjusted on this buffer by turning the orange wheel. The wheel is set to 3. A chart above the wheel gives the rotation speed for each number.*

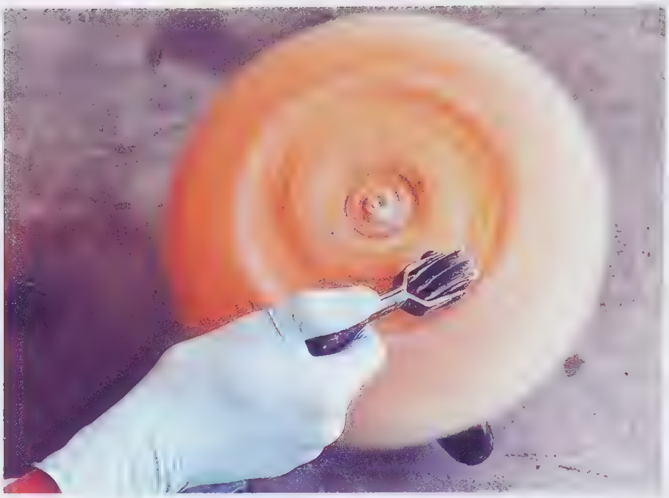


Figure 32-9. *The compound must be dry on the pad for a spur to work. Hold the spur firmly and wear eye protection.*

WARNING

The spinning pad will grab anything in its reach. Keep the electric cord out of the way. Tuck in your shirt. Avoid buffing near edges and bodylines, as well as near the antenna, windshield wipers, and moldings.

Dried abrasive on the pad can cause swirl marks. See **Figure 32-8**. Cleaning the pad regularly is the only way to avoid them. Wool pads are cleaned with a spur, **Figure 32-9**. The spur is held firmly against the rotating pad to clean off the dried compound. A foam pad can be cleaned with a brush as shown in **Figure 32-10**. Spur or brush cleaning will not remove all the dried compound from a pad. Wool pads can be laundered in a clothes washing machine, and foam pads can be soaked overnight in a cleaning solution.

Today's clearcoat urethanes become very hard when fully cured. This makes the clearcoat surface scratch resistant, but it also makes buffing a fully cured clearcoat difficult. The solution is to buff the clearcoat before it cures completely. A ***buffing window*** is the short span of time a fresh urethane clearcoat can be easily buffed; it is the "sweet spot" between too wet and too hard.

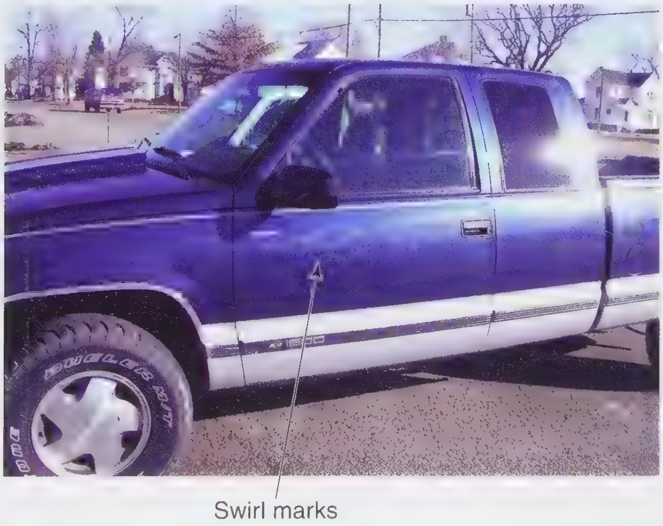


Figure 32-8. *Swirl marks left by compounding are clearly visible. This vehicle needs to be polished, glazed, and waxed.*

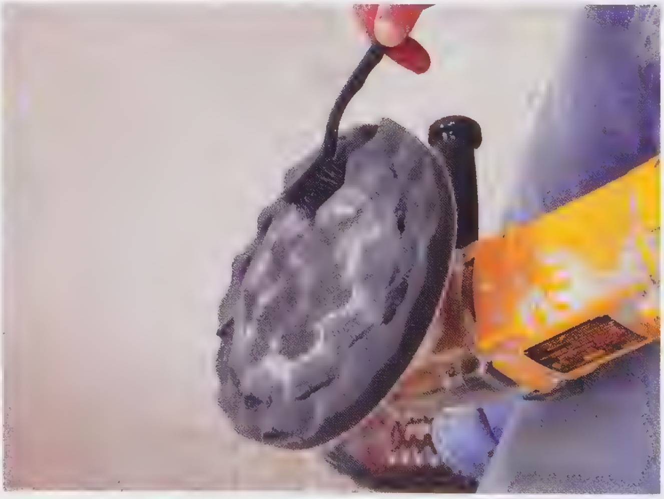


Figure 32-10. *A brush held against a spinning pad will remove dried compound.*

The buffing window varies, depending on the paint manufacturer. Also, the same paint manufacturer may offer several types of clearcoat, each with a different buffing window. For example, the buffing window for one type of high-production clearcoat is from four hours after spraying (air dry) to four days after spraying. Another type of clearcoat has a much smaller buffing window: from eight hours after spraying (air dry) to 16 hours after spraying. On a fresh urethane basecoat/clearcoat finish, buffing may reduce the shine of the clearcoat.

Glazing

A glaze is applied to the paint surface after buffing and polishing. The ***glaze*** will fill and hide swirl marks, but the effects are temporary. The glaze will quickly evaporate when exposed to direct sunlight and a single washing will remove it all. The only way to protect glaze is with a coat of wax applied immediately after application.

Glazing is done by hand or with a buffer fitted with a foam polishing pad. Whether you are performing this task by hand or with a machine, limit the amount of glaze applied to the surface. Only a small quantity is needed.

When applying glaze by hand, apply a few drops to 1 sq ft area. Work the glaze into the surface with a soft cloth, wipe it off with a detail cloth, and then do the same to an adjacent one-foot square area.

When using a buffing machine, work the glaze into the surface. The glaze will dry as the pad spins. Wipe off any excess glaze with a detail cloth.

NOTE

A detail cloth is a soft cloth designed for contact with painted surfaces.

CAUTION

Wiping a painted surface with dry cloth may cause scratches in the paint if the paint surface or the cloth contains grit or abrasive residue left behind after compounding or polishing.

Paintless Dent Repair

Paintless dent repair involves pushing out, or raising, a low area in a panel without damaging the paint. Paintless dent repair requires skill that can only be developed through considerable practice. A set of paintless dent repair tools is shown in **Figure 32-11**. The rods are inserted into a panel to access the underside of the dent. The tip of the rod is used to push against the dent. With each push, a small amount of the dent is raised.

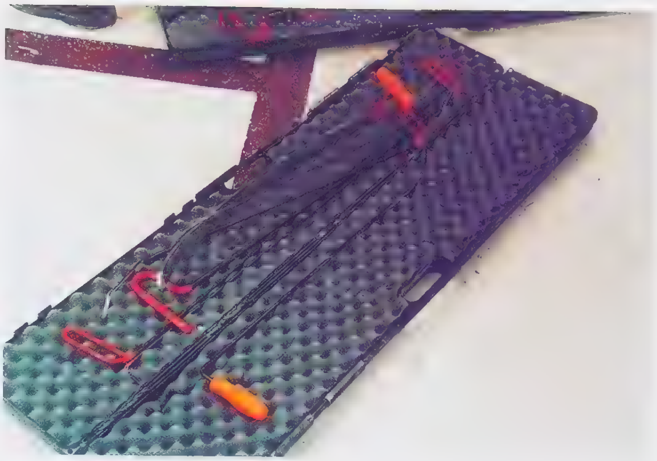


Figure 32-11. *These paintless dent repair tools are slipped inside panels to raise dents.*

Begin the paintless dent repair process by examining the dent. If the paint is chipped or cracked, the area will need to be repainted. Therefore, paintless dent repair is not the best choice in these situations. A dent the size of a quarter or smaller is a good candidate for paintless dent repair, although a skilled technician can remove dents the size of a silver dollar or even larger.

Access to the back of the panel is required for paintless dent repair. Movable panels, such as doors, hoods, and deck lids, should be propped open and secured so they cannot move during the repair. Interior parts or liners may have to be removed to repair a door, quarter panel, or roof. Be careful. There is always a possibility of breaking plastic parts or fasteners during removal. Another method of access on fender dents is to remove a headlight or the fender liner. On quarter panel dents, the trunk liner may need to be removed. To access door dings, the window opening can be enlarged by inserting a plastic wedge between the window and the door skin. Some technicians drill a 1/4"–3/4" hole on the inside portion of a door or wheelhouse, or use existing holes in the doorjamb. The hole provides access for the dent repair rod. After the dent is repaired, a plastic plug is used to cover the hole. **Figure 32-12** shows how to access the back of a panel.

The ability to locate the dent from the back side of the panel is essential to successful paintless dent repair. A dedicated light system or mirrored target board positioned on the outside of the panel will help the technician locate the dent and monitor progress. The light or target board projects straight lines across the panel. The dent is seen as a wave in the otherwise straight lines. As the dent is pushed out, the wave is removed and the lines will appear straight.

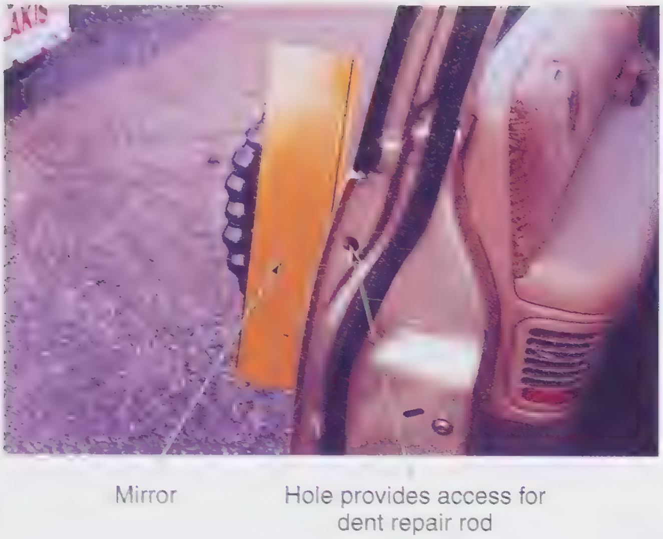


Figure 32-12. *A hole has been drilled in the door frame for access to the back side of the door skin. After repair, the hole will be filled with a plastic plug. Notice the mirror, which is positioned to reflect a straight-line pattern onto the door. The dent is seen as a wave in the straight line. As the dent is pushed out, the wave is removed and the lines will appear straight.*

After positioning the light or mirror, insert the correct rod to access the back of the dent. The rod requires a surface to rest against for leverage. See **Figure 32-13**. A block of wood can serve as this surface. The longer the rod, the more force can be applied to raise the dent.

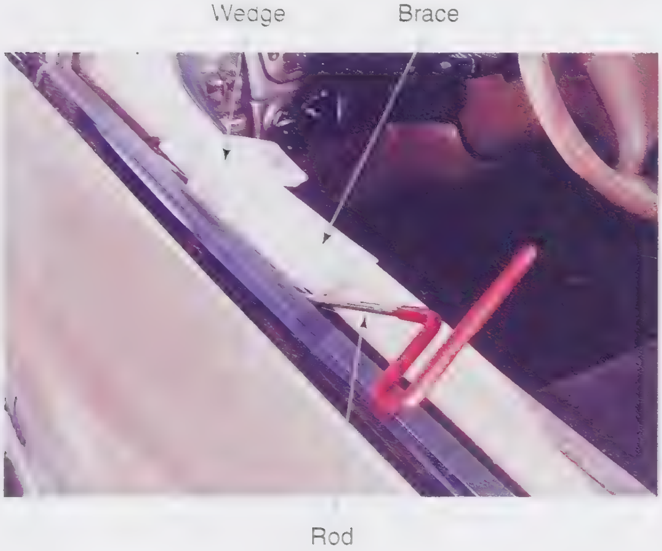


Figure 32-13. *The window opening of a door is wedged apart for better access to the back side of the door skin. The rod will use the brace that supports the wedge for leverage.*

Locate the tip of the rod by pushing out slightly on the panel. The tip of the rod will make a slight bulge when pushed against the panel. Locating and properly positioning the tip of the rod is the most important and most difficult part of paintless dent repair. Experienced technicians can locate the dent by feeling for it with the tip of the rod.

There are two ways to remove a dent, the pull/push method and the push method. The first method requires pulling and pushing the rod across the dent. In the second method, the technician pushes out on the dent with the rod tip.

In the ***pull/push method***, position the tip of the rod at the far edge of the dent. Pull the rod about halfway across the dent, exerting the most pressure when the rod tip is at the deepest part of the dent. See **Figure 32-14**. Next, position the rod at the near edge of the dent. Push the rod toward the center of the dent, exerting the most pressure and pausing at the deepest part of the dent. Continue making pulls and pushes until the dent is nearly removed. When only a slight dent remains, use the rod tip to raise what remains of the dent. The last bit of the dent will be the most resistant. Therefore, it will require the greatest amount of leverage and pressure.

In the ***push method***, the technician raises the dent with the tip of the rod by making a series of small, delicate reverse dents in the panel. See **Figure 32-15**. These reverse dents are so subtle that they are not visible. There are two ways to push the dent. The first method starts at the edge of the dent and progresses toward the center. The second method starts in the center and progresses outward. The first method is shown in **Figure 32-16**. Pushes are made around the edge of the dent. As the edge is raised, the dent becomes increasingly smaller. Working in a circular pattern around the edge of the dent, a continuous series of many small pushes raises the dent level with the surrounding metal. The last remaining part of the dent, in the center, is the most difficult to raise.

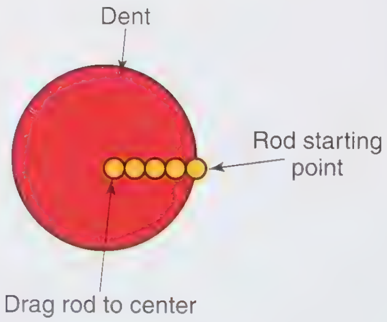


Figure 32-14. *The rod tip is positioned at the edge of the dent and is dragged toward the center in the pull/push dent repair technique. The most pressure is exerted at the center, the deepest part of the dent.*

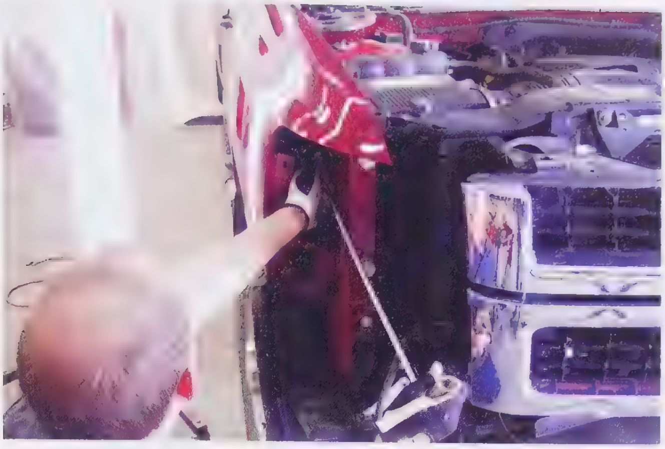


Figure 32-15. *This technician is using the push method on these fender dents. The headlight has been removed to gain access to the back of the dent.*

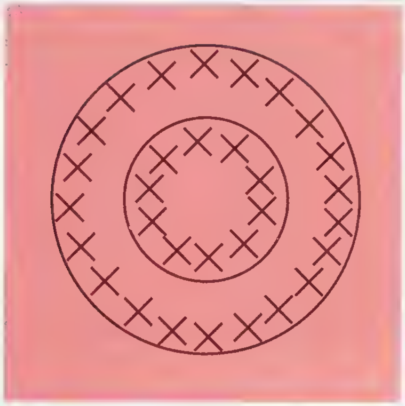


Figure 32-16. *In this paintless dent repair technique, a series of small pushes are made around the edge of the dent, gradually working in a circle toward the center.*

When performing the second push method, start at the deepest part of the dent and raise it slightly, making a small reverse dent. Then find the next deepest part and raise it slightly. Continue slightly raising the deepest part of the dent until the dent is gone. If a slight high spot results from pushing, a nylon rod can be placed on the high spot and tapped with a hammer to lower the spot and bring it level with the surrounding surface.

With any paintless dent repair technique, check the paint after making the repair. Use a magnifying glass to examine the paint at the point of repair. Cracks or breaks in the paint, no matter how small, will allow moisture to reach bare metal and cause rust. If cracks or breaks are found in the paint, the panel must be repainted to provide corrosion protection. Some manufacturers recommend that the back of the panel be sprayed with an epoxy primer or rustproofing to cover up any scratches that expose bare metal.

NOTE

The pull/push method works best on a bodyline, while the push method is good for a dent in a low-crown surface.

Small dents that cannot be accessed from the back of the panel can be removed using a glue-on pull tab. Hot-melt glue temporarily attaches a pull tab to the panel. The pull tab is raised with a slide hammer or lever. **Figure 32-17** shows the repair sequence. The panel should be cleaned with wax-and-grease remover and the dents should be located. Various shapes and sizes of pull tabs are available. Select a pull tab that will fit into the deepest part of the dent. The pull tab point is coated with hot-melt glue as shown in **Figure 32-17A**. Immediately position the pull tab point at the deepest part of the dent. **Figure 32-17B** shows a pull tab in place. Use a slide hammer to pull the tab, **Figure 32-17C**, raising the dent. Light slide hammer blows will raise the dent. Do not raise the dent above the surrounding metal. Remove the pull tab by twisting.

Painted Stripes

Painted stripes can be time-consuming to apply, but the procedure is straightforward. **Figure 32-18** shows a stripe arrangement on a conversion van. Usually there will be a tag inside the driver's door that lists the part number of the paint used to make the stripes.

Stripes may be straight and level or they may follow the contour of the body. The technician who installs stripes and moldings must have the ability to recognize a straight and level condition. The ability to sight straight and level can be gained with practice. To evaluate a vehicle, start by viewing the side of the vehicle from about twenty feet away. Next, look at the vehicle from one end, sighting down the side. Try to identify any dips in the stripe.

When repairing a vehicle with painted-on stripes, panels are first painted the main color of the vehicle. When the main color has cured, the stripes can be laid out. Fine-line striping tape is available in a variety of widths, including 1/16", 1/8", 1/4", 3/8", and 1/2". If part of the original stripe arrangement is still on the repaired side of the vehicle, it can be used as a guide when laying out the new stripes. If the entire side has been painted, the technician must take measurements from the other side of the vehicle to lay out the stripes.

Figure 32-19 shows a technician masking the design at the front end of a stripe. The technician stretches the tape to help keep it straight. (This is a two-tone stripe.) If the stripes are multiple colors, each color will be sprayed separately. This is done by laying out the pattern with fine-line tape and then masking off all but one color. The one color is sprayed. Once it is dry, it is masked and another color is unmasked and sprayed.

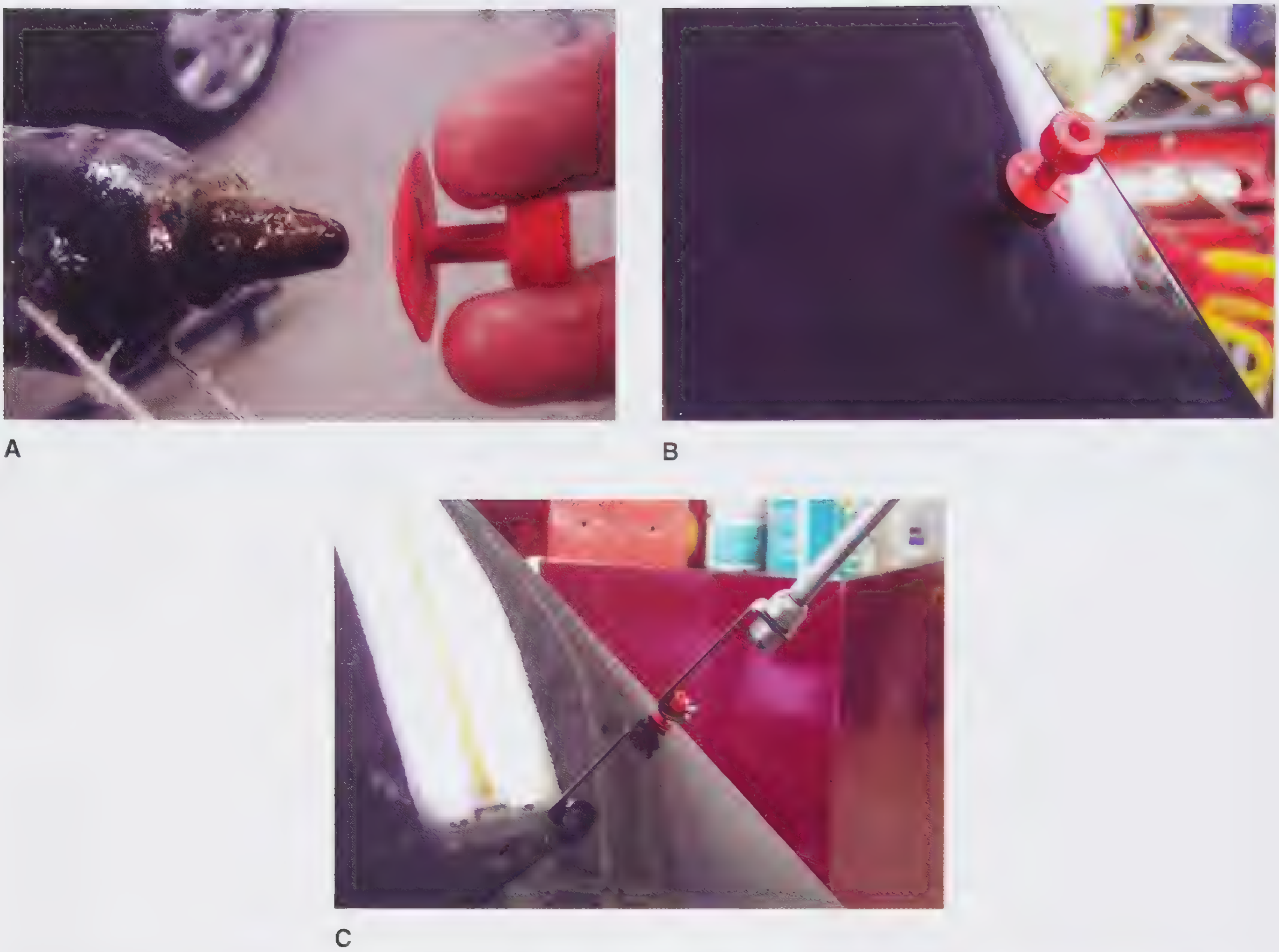


Figure 32-17. *A—Small dents that cannot be accessed from behind can be removed by using a glue-on pull tab. A glue gun is used to apply glue to the pull tab. B—The pull tab is attached to the panel. Notice the marker outline around the dent. C—A slide hammer raises the dent. Be careful. You do not want to raise the dent above the surrounding metal.*

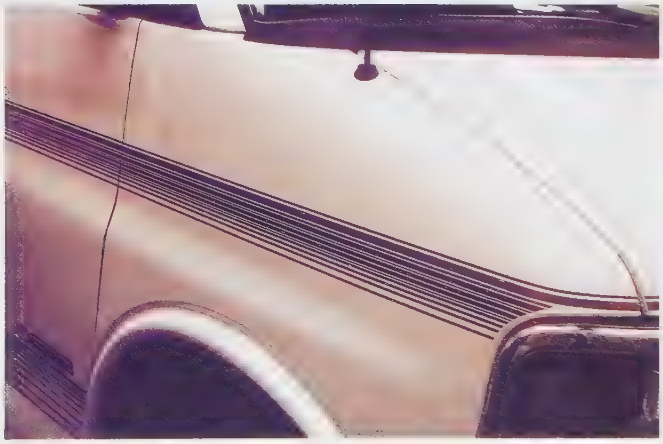


Figure 32-18. *This van has a painted-on stripe design. If color matching is a problem, the stripe color can be blended.*

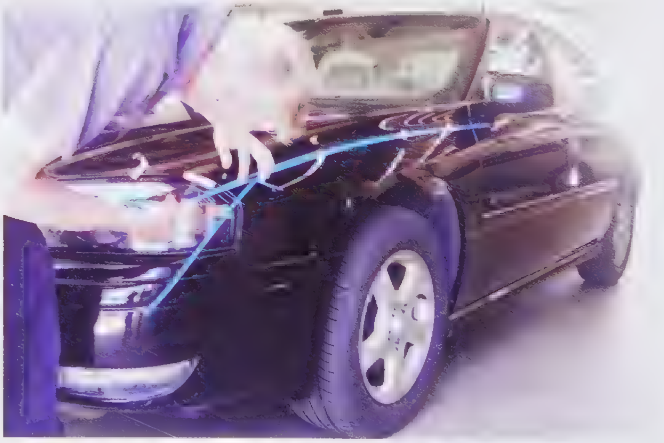


Figure 32-19. *This fender was repainted. The stripe is masked off with fine-line tape. The stripe on the door will be blended.*

NOTE

If color matching is a problem, the stripe color can be blended.

This process continues until all the colors have been sprayed. The masking is then removed from the stripes, but it is left on the main color. The stripes are then clearcoated.

Installing Pinstripe Tape

Pinstripe tape is installed after the vehicle has been buffed. Begin by cleaning the surface with wax-and-grease remover. If an entire side will be striped, apply striping tape to all the panels at one time rather than to each panel individually. For example, do not begin by applying a piece of pinstripe tape to the fender, followed by another piece of tape on the door, and then the quarter panel. Instead, use one long length of pinstripe tape and do all three panels at one time. This is the only way to get a straight line.

Measure out the required amount of pinstripe, allowing a few extra inches. The pinstripe consists of a paper backing, the pinstriping tape, and a clear plastic cover. The actual pinstripe tape is sandwiched between the paper backing and the plastic cover.

NOTE

Some paint manufacturers require that the refinish paint dry for at least 48 hours before applying pinstripes and one week before applying large or thick decals. The dry time allows complete evaporation of all the solvents in the refinish paint. Blistering may result if the solvents are trapped in the paint by a decal.

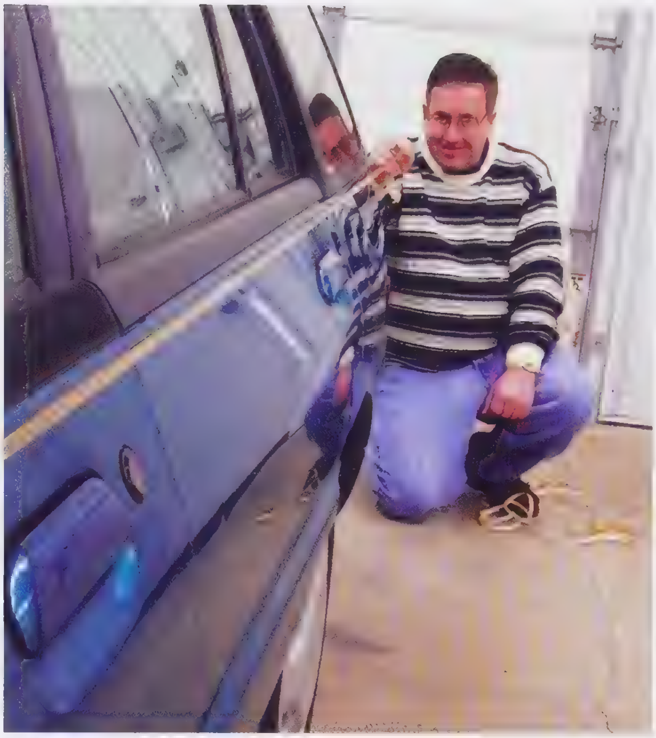


Figure 32-20. *This technician is checking the pinstripe tape for level by sighting down the length of the vehicle. Note that one length of pinstripe tape is used for the entire side.*

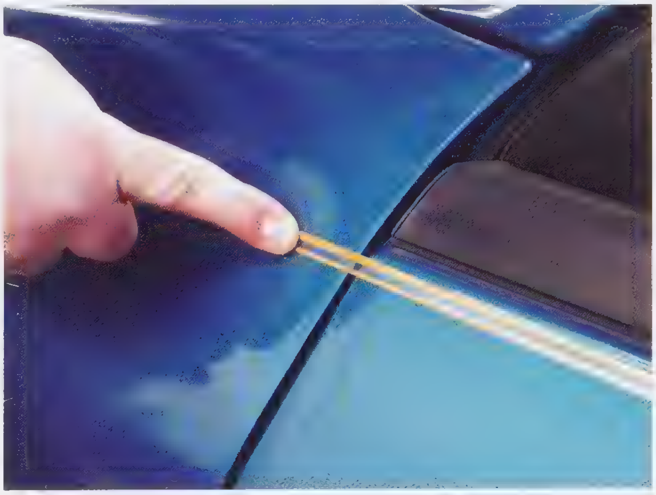


Figure 32-21. *Once the stripe is positioned properly, press it into place.*

Remove the paper backing from one end of the pinstripe tape. The back of the tape is coated with adhesive; the front side is not. Place the sticky side of the tape against the vehicle surface. Attach the tape to one end of the panel or the vehicle. Pull off the paper backing and stretch out the tape. By sighting along the length of the panel, the technician can visually determine if the tape is straight. When the tape is straight, lightly attach it to the surface. Do not yet press it down firmly. Double check the stripe to make sure it is level, or make sure it follows the vehicle's contour. In **Figure 32-20**, the technician is looking for areas where the stripe is not level. If a reference point, such as a bodyline, is available, the stripe should be a uniform distance from it along the entire length.

If the stripe is not positioned properly, gently lift to remove and reset it. Once the stripe is in the right location, press down on the tape as shown in **Figure 32-21** to lock it in place. Next, remove the plastic cover from the tape. Be careful not to disturb the stripe. After the plastic cover is removed, the door openings can be cut out using a razor blade. See **Figure 32-22**. After cutting, fold the edges of the tape back to the underside of the panel. If the stripes need to be brought together to form an end,

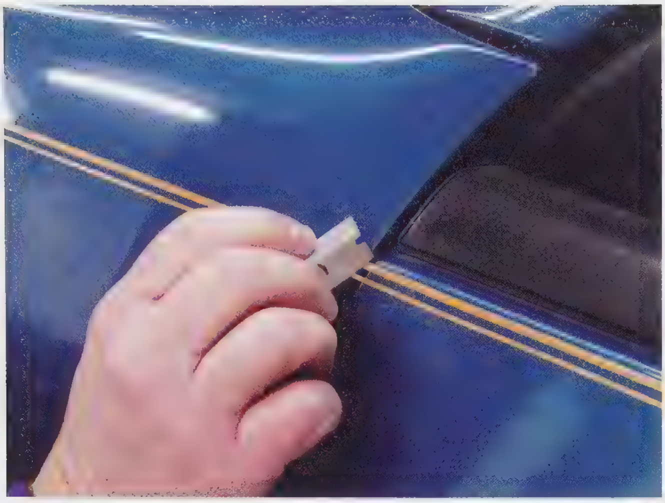


Figure 32-22. *Cut the stripe with a razor blade at the panel openings. Then fold the edges back to the underside of the panel.*

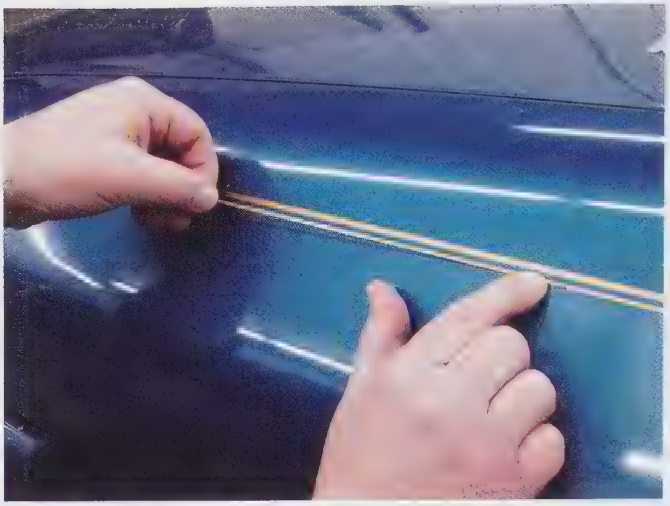


Figure 32-23. *The narrow section of the stripe has been broken. A new narrow stripe is positioned and will be cut to fit.*

lift up one or both of the stripes and move them into place. If the narrow stripe breaks, it can be fixed by splicing in a section of new stripe and overlapping it slightly on the existing stripe. See **Figure 32-23**.

If the stripe size is not standard, bulk tape can be cut to the required width on a tape slitter. The slitter is set to the required width and the bulk tape is fed through.

Adhesive-Attached Plastic Molding

If adhesive-attached moldings are reused, all the original adhesive must be removed from the molding. If any of the original adhesive remains, the molding will not properly adhere to the vehicle.

A quick way to remove adhesive is to heat the blade of a putty knife with a propane torch. The hot blade will soften and scrape away the adhesive. If the molding has a thin, foil-like metal backing that was bent during removal, grind off the metal backing as shown in **Figure 32-24**. Grinding it off will allow the molding to return to its original shape. The metal backing is thin. Grinding off the backing will not significantly change the thickness of the molding. If plastic moldings without a metal backing are bent, placing them in the sun or under a heat lamp will help restore their shape.

Apply double-sided tape to molding that will be reused. See **Figure 32-25**. Leave the top plastic cover on the molding tape. Clean the panel with wax-and-grease remover. Body side moldings are usually

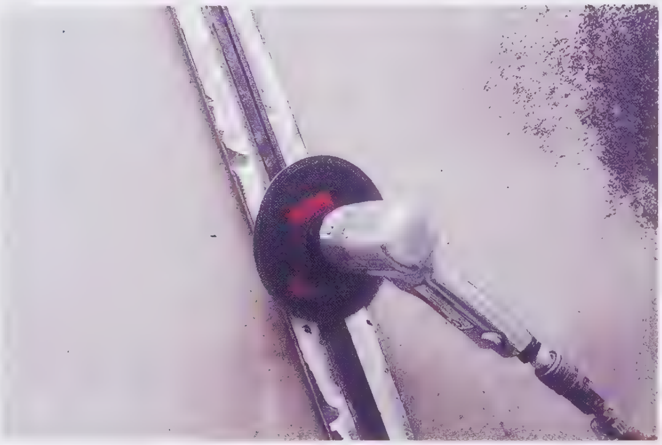


Figure 32-24. *If the metal backing on the molding is bent, the molding will not be straight. Grinding off the metal will straighten the molding.*

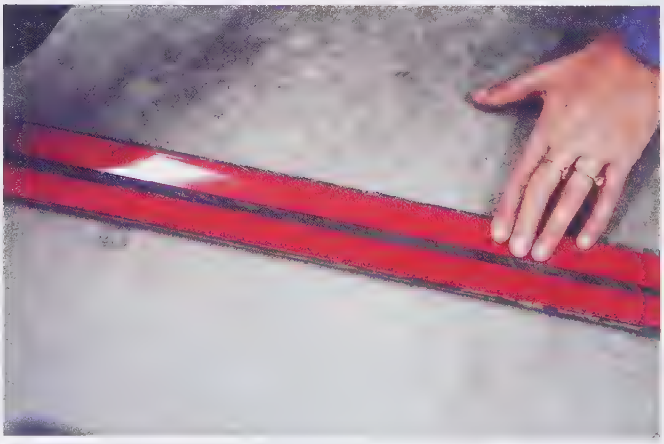


Figure 32-25. *After cleaning off all the original adhesive, double-sided tape is installed on the molding.*

installed straight and level. Apply masking tape to the side of the vehicle as shown in **Figure 32-26**. The masking tape will serve as a reference for the bottom of the molding. Step back and make sure the masking tape is straight.

NOTE

Door moldings may have to be set back from the front edge of the door to prevent contact with the fender when the door is opened. Check the other side of the vehicle to determine if this is necessary.

Peel the upper plastic cover off the molding tape. Set one end of the molding in place, using the masking tape as a guide. Stretch the molding to the other end of the panel, being careful not to let the center droop. Lightly push on the molding to set it in place. Step back and make sure the molding is level. If the molding must be repositioned, try pushing up or down on the molding rather than pulling the molding off the panel. If the molding is level, push down on it to permanently fix it in place. Once molding tape is pressed on the vehicle, it will not come off without damaging the paint or the molding.

NOTE

The guidelines for installing adhesive-attached moldings also apply to installing nameplates.

Riveted-on Molding Clips

A riveted-on molding clip is shown in **Figure 32-27**. The rivets are welded to the vehicle at the factory. A replacement panel will not have rivets. New rivets can be welded on using a draw pin welder, so bare metal is needed at the weld site.

Instead of welding on new rivets, most shops install the molding clips with pop rivets or sheet metal screws. To install the clips in this manner, hold the molding in the proper position on the panel and lightly trace around the molding with a pencil. Remove the molding. Look at the back of the molding and measure the position of the clips. Transfer these measurements to the traced outline of the molding on the side of the vehicle.

Position the clips on the panel as shown in **Figure 32-28** and mark the locations where the rivets or screws should be placed. Remove the clips and drill 1/8" holes at the marks. If possible, drill the holes before the panel is painted. In this way, the holes can be sprayed with primer and paint so the edges will not rust. If the holes must be drilled after the panel is painted, apply primer to the bare metal around the inside edge of the holes. Position the clip and install steel pop rivets or sheet metal screws. Snap the molding on the clips.

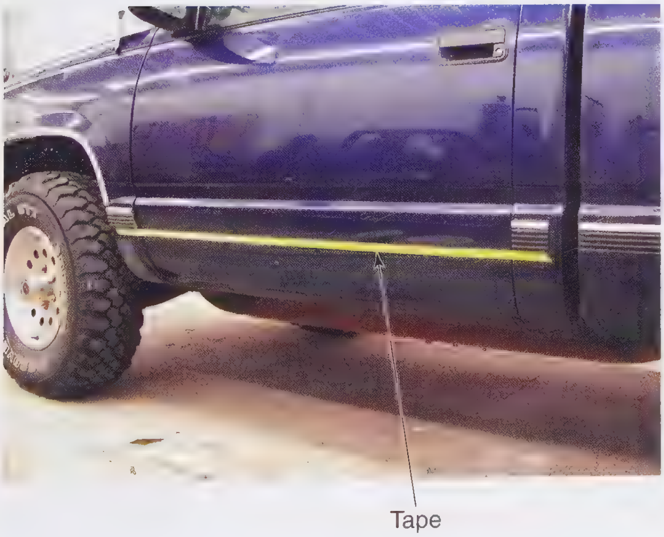


Figure 32-26. *Masking tape can be used as a guide when installing a molding. Install the masking tape straight and line up the molding with the edge of the tape.*

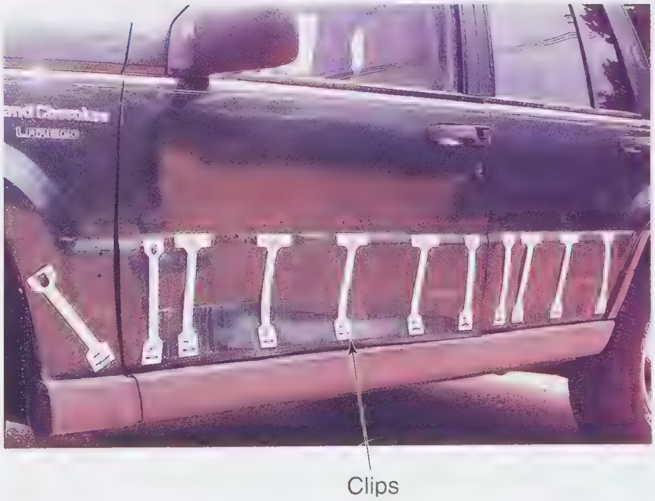


Figure 32-27. *The molding clips on this vehicle are held in place by rivets that were welded on during manufacture. The clips are removable; the welded rivets are not.*

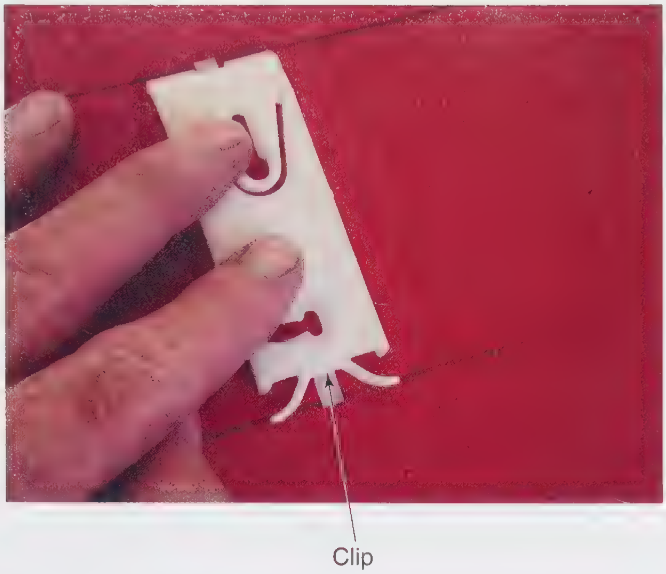


Figure 32-28. *Use the outline to decide where the clip should be positioned. Pop rivets or sheet metal screws fasten the clip to the vehicle.*

Decals

Decals are typically used as a form of decoration or an extension of the vehicle's design. They serve a practical purpose too when applied as protection in front of a rear wheel opening. Decals vary in size. Some are as small as 2" in diameter, while others cover an entire panel. Decals smaller than 6" in diameter are generally installed dry. Decals larger than 6" in diameter are usually installed wet. Wet installation allows the decal to be positioned before it adheres to the surface. In a dry installation, the decal immediately adheres to the surface.

Patience is required when working with decals. Once a dry decal is installed or a wet decal is positioned and dries, there is no possibility of moving it. Besides positioning, other potential problems include folds and air bubbles. Folds are caused when the decal overlaps itself. Bubbles are caused by trapped air. These problems can be avoided by carefully installing the decal.

Decals are installed after the vehicle is painted and buffed. The technician must have clean hands when installing a decal. Any dirt on the technician's hands will be transferred to the adhesive on the back of the decal. If the contaminated part of the decal is transparent, the dirt will show through and will never come off.

Small Decal Installation

Small decals are generally between 2" and 6" in diameter and are usually installed dry. To apply a small decal:

1. Clean off the area.
2. Make a reference line with masking tape. The edge of the decal will be applied at the reference line. See **Figure 32-29**. A bodyline, such as a wheel opening, can also serve as a reference line.
3. Remove the paper backing from the decal to expose the adhesive.
4. Attach one edge of the decal to the reference point or line.
5. Stretch the decal lengthwise and apply it in a rolling motion as shown in **Figure 32-30**.
6. If necessary, release air bubbles by poking with a pin.

Large Decal installation

A decal that is 6" or more in diameter or width is considered a large decal. Some decals, such as wood grain decals, may cover an entire panel. These large decals are set over a wet surface. Water allows the decal to be positioned before it adheres. To apply a large decal:

1. Clean the surface.
2. Place the decal in a bucket of warm, soapy water. Allow the decal to soak for 5–10 minutes.

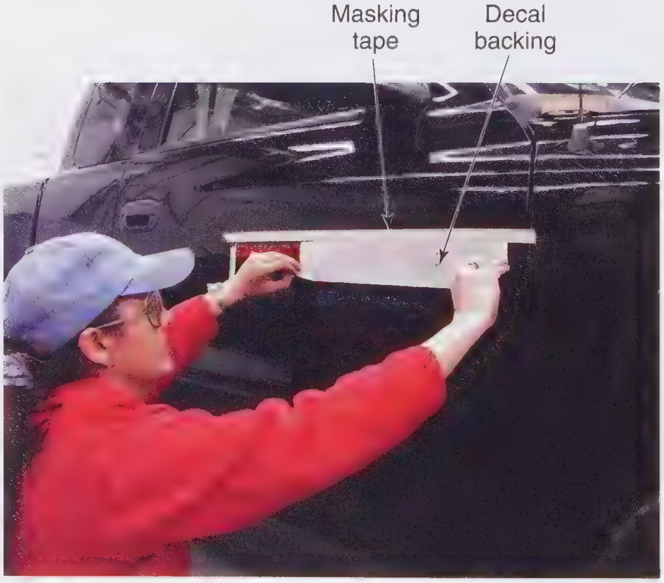


Figure 32-29. *The masking tape is the reference line. The edge of the decal backing is positioned against the tape.*

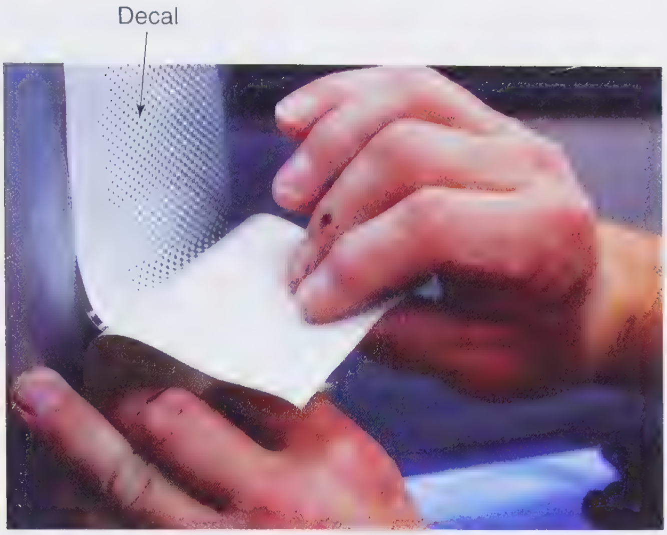


Figure 32-30. *The decal must be stretched tight while rolling off the backing.*

3. Use a spray bottle to wet down the area where the decal will be applied.
4. Remove the decal from the bucket and peel off the paper backing.
5. Position the top edge of the decal in the proper location while holding the bottom edge out of the way.
6. Use a squeegee to remove water from under the decal. See **Figure 32-31**.

When the entire decal has been laid out, use the squeegee to work out any folds and bubbles. Work from the center of the decal to one edge. Then go back to the center and work to the other edge.

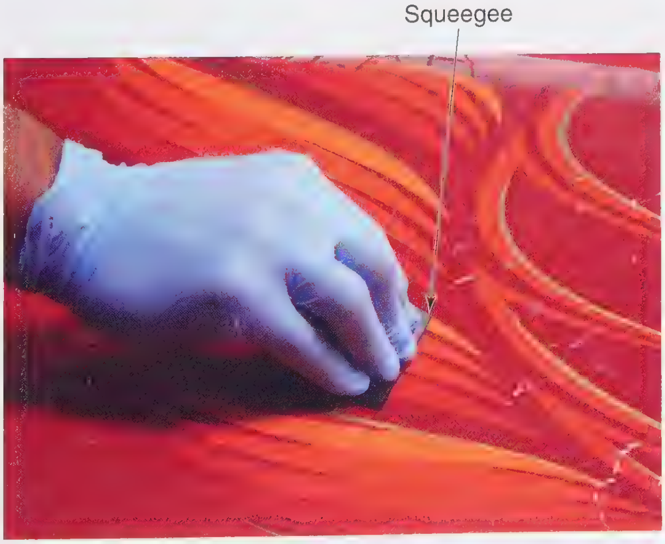


Figure 32-31. *A squeegee is used to remove water from under the decal. Folds and bubbles are removed as well.*

When the decal is positioned properly, use the heat gun to speed up the drying process. If the decal must be stretched to go into a door handle opening or another tight fitting area, heat the decal and carefully push it into place.

Clean Up

Bodywork and painting may leave the repaired vehicle covered with dust and overspray. Proper masking will prevent overspray, and some shops cover all vehicles with masking plastic to minimize dust problems. Regardless, vehicles should be cleaned up before being delivered to the customer.

To correct appearance problems, some body shops make the extra effort to detail all customer cars before delivery.

NOTE

Some of the problems corrected during detailing may have existed before the vehicle was brought into the shop.

Begin detailing by cleaning the inside of the vehicle. If personal items, such as child car seats, cups, toys, books, etc., were left in the vehicle, remove them before cleaning and replace them when you are finished. Open the doors and blow the dust from the carpet, seats, and dash. See **Figure 32-32**. Vacuum the seats, carpets, and air ducts. Use a tack rag to remove remaining dust from the dash, gauges, door panels, and console.

Figure 32-32. *Vehicles should be detailed before being delivered back to the customer. Begin by cleaning the interior. With the doors open, use an air gun to blow dust out.*

A spray fabric cleaner can be applied to carpet and cloth seat stains. The cleaner must usually set for a few minutes after application. Dirty carpet may require that the seats be removed for proper cleaning.

Use a plastic-safe cleaner on the dash, steering wheel, console, and other plastic parts inside the vehicle. After cleaning, apply a plastic dressing to plastic parts. The dressing will leave a glossy, protective layer. Apply dedicated leather dressing to leather seats. Likewise, use a window cleaner on the inside of the windows.

After cleaning the interior, turn your attention to the engine compartment. A warm engine is easier to clean, as the heat softens and loosens grease and oil making them easier to remove. Apply an engine cleaner to the engine, avoiding the ignition system, computer, and throttle body components.

CAUTION

Avoid spraying cold water on a hot engine.

Allow the cleaner enough time to soak into the grease and oil. Then wash the engine compartment with a high-pressure hose and hot, soapy water. An engine dressing can be sprayed over the engine to give it a like-new appearance.

Next, remove overspray. Overspray may be found anywhere on the vehicle after painting. Overspray on glass can be scraped with a razor blade as shown in **Figure 32-33**. Be careful not to scratch the glass. Remaining overspray can be removed with a rag dipped in lacquer thinner. Do not allow the lacquer thinner to drip on to the paint. Overspray on an unpainted, black plastic parts or tires can be removed with lacquer thinner.

Tires can be difficult to clean because the overspray may be in the crevices of the tread. If the wheel well or chassis has overspray, apply black paint or undercoating to cover the problem.

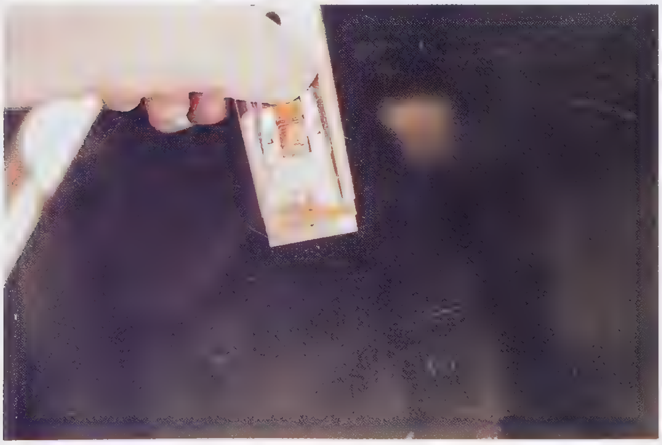


Figure 32-33. *Remove paint overspray from a windshield by carefully scraping it off with a razor blade.*

Overspray on painted surfaces can be color sanded and buffed. Abrasive blocks, which are available in various grits, can be used to remove heavy overspray. These blocks are like sandpaper in block form. Start with a 3000-grit abrasive block. If this does not remove the overspray, try a 2000-grit abrasive block. After using the abrasive blocks the paint must be buffed.

A clay bar is an engineered resin compound that resembles the modeling clay you played with as a child. It is used to remove contaminants from the paint surface and windows. Clay removes many contaminants that soap-and-water washing cannot. Tar, bugs, tree sap, brake dust, rail dust, acid rain deposits, and industrial fallout are all effectively removed by a clay bar.

Light overspray can be removed with a clay bar. It pulls contaminants from the surface of the paint. A lubricating liquid must be applied to the painted surface before using the clay bar. Form the bar to conform to the shape of the panel, apply the lubricant, and rub the bar over the paint using straight, back-and-forth strokes.

NOTE

Vehicle must be washed before and after using a clay bar.

Flatten the clay bar and shape it so the entire under surface contacts the paint. If only a portion of the clay bar's under surface contacts the paint, then only a portion of the overspray will be removed. You will feel a roughness and hear a slight scratching sound as the clay bar is rubbed over contaminants on the paint. Contaminants will adhere to the clay bar and may cause scratches with continued rubbing. Fold and flatten the clay bar to expose fresh, uncontaminated clay. Continue rubbing the wetted surface until the roughness is removed and the clay bar smoothly glides over the paint. Use a soft cloth to wipe off any remaining lubricant. See **Figure 32-34**. The panel will not need buffing after using a clay bar.

NOTE

A clay bar is also an effective way to remove overspray from glass.

Wheels may be contaminated with brake dust. Wash it off with soap and water or a dedicated wheel cleaner. If necessary, use a soft brush to remove the dust from recessed areas of the wheels.

Road tar on lower body surfaces, such as rocker panels, can be removed with wax-and-grease remover. To remove a thick layer of tar, soak a rag in wax-and-grease remover and hold it against the tar for a few minutes to soften the material.

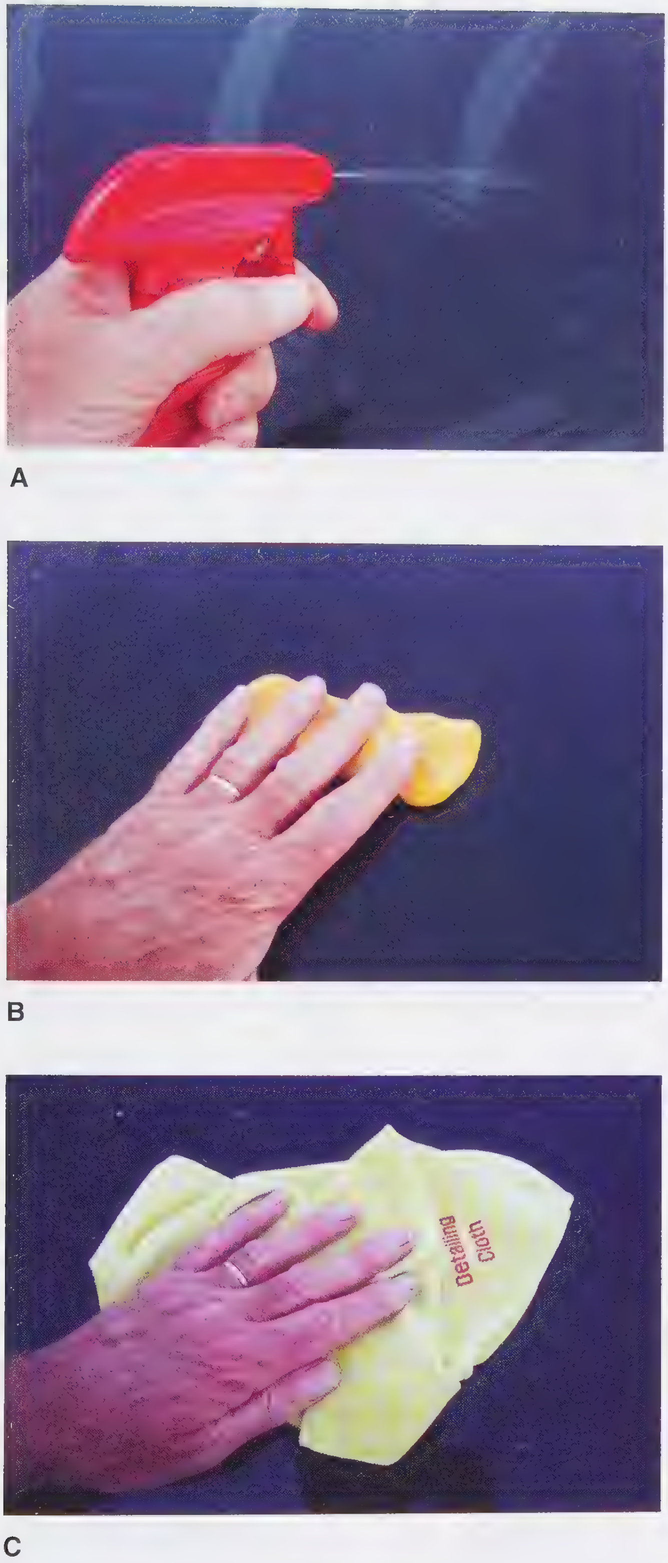


Figure 32-34. *A—When using a clay bar to remove contaminants, apply lubricant from a spray bottle to cover a 2' x 2' work area. B—Keep the clay bar flat on the surface so the entire bottom of the bar is in contact with the paint. C—When done, use a detail cloth to remove excess lubricant.*

Dead bugs on chrome, chromed plated plastic, or painted parts can be removed with a polish. The mild abrasive in the polish will rub off the bug carcasses. Rust spots on chrome can be temporarily removed by hand rubbing with compound.

After removing overspray, cleaning the wheels, and removing tar and bugs, wash the vehicle with soap and water. Start by spraying off the wheel wells and the wheels. Next, wet down the vehicle's body, starting at the top. Spray the roof, hood, and deck lid, followed by the sides. Buffing compound or polish may have built up around the windshield wipers or cowl vent. Be sure to spray these areas thoroughly.

After wetting down the entire body, wash the vehicle, again starting at the top and working your way downward. Rinse each panel or section thoroughly after washing. A soft water rinse will minimize mineral deposits. Dry the vehicle with a squeegee, followed with a microfiber drying towel.

After washing, apply a tire dressing. If the windows have water spots, use a glass cleaner on the outside glass. This is usually the last step before delivery. Some body shops display completed vehicles in front of the shop as advertisement.

WORKING GREEN

Many cities require that detailing and car wash operators take steps to prevent wash water from discharging into storm drains. The EPA is enforcing the Clean Water Act of 1972 and will penalize businesses that allow the discharge of untreated wash water into storm drains.

Removing Paint Surface Defects

Weathering, environmental pollution, parking lot damage, and errors made during refinishing are some of the causes of paint surface defects. This section describes common paint surface defects and explains how to correct them.

Removing Orange Peel

All repaints will have some degree of orange peel. ***Orange peel*** is a condition where the paint surface is not smooth but dimpled and resembles the surface of an orange. It is caused by either improper spray gun adjustments or incorrect spray technique. If orange peel is excessive, the clearcoat can be color sanded and buffed to remove it. The steps for removing orange peel are as follows:

1. If the orange peel is rough to the touch, start color sanding with 1500-grit sandpaper. Sand only until there are no visible shiny dots. Do not sand more than necessary. **Figure 32-35** shows what orange peel looks like during color sanding. In this example, additional sanding is called for.
2. After sanding, buff the area with a wool pad and rubbing compound. Buff the area until the paint shines.
3. Polish the compounded area with a foam pad and polish. Buff the area until the desired level of gloss is achieved.
4. If necessary, work glaze into the polished area. Glaze will fill and eliminate swirl marks. The glaze can be applied by hand or with a machine.
5. Immediately follow glazing with a coat of wax.

Dirt Particles

Dirt creates bumps in the painted surface. Small dirt particles can be seen. Large dirt particles can be seen and felt. **Figure 32-36** shows dirt in the clearcoat. A small cylindrical sanding block wrapped in 1500-grit sandpaper can be used to sand out the dirt, see **Figure 32-37**. A dual-action sander and 1500-grit sandpaper can be used to power sand the dirt spot. Sand with 1500-grit paper until the dirt can no longer be felt.

NOTE

If, in addition to dirt, orange peel is also present on the panel, remove the dirt as described previously and color sand the entire panel.

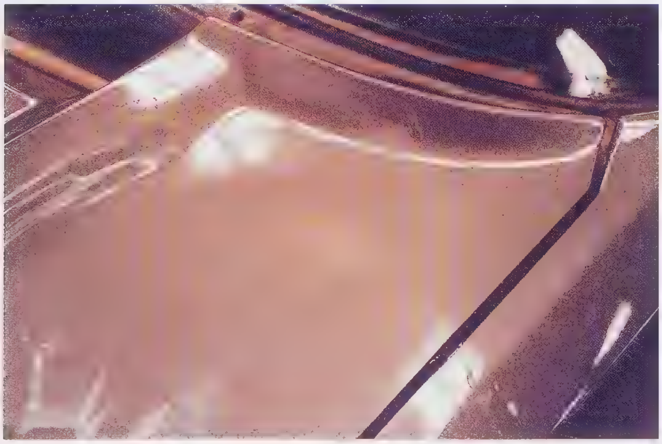


Figure 32-35. *Shiny dots in the sanded area indicate orange peel. Keep color sanding until all the shiny spots are gone.*

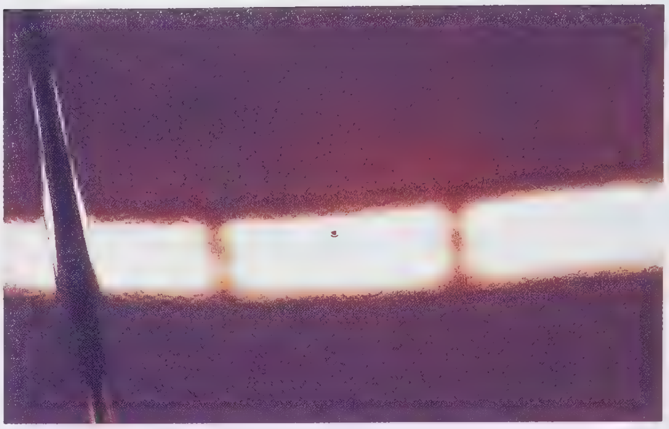


Figure 32-36. *A piece of dirt is visible in the clearcoat. A razor blade can be used to remove big particles of dirt from the clearcoat.*

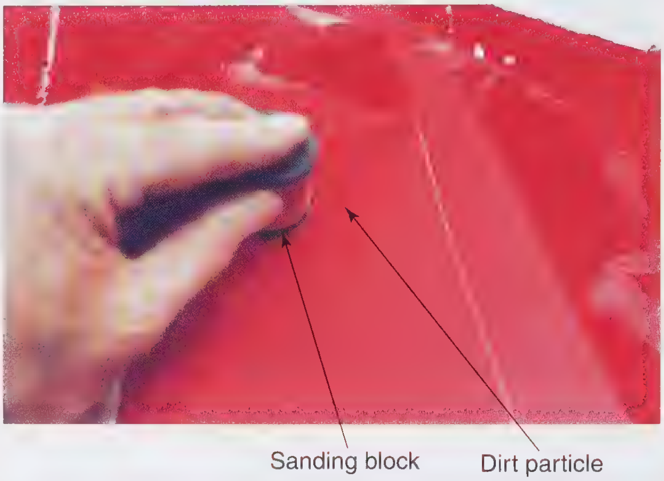


Figure 32-37. *This small sanding block concentrates the abrasive action on a small area. It helps avoid sanding the clearcoat around the defect.*

After using the 1500-grit sanding disk, buff the sanded areas with polish and a foam polishing pad. Apply firm pressure to the buffer to remove the 1500-grit scratches. After the scratches are removed, reduce the pressure and buff the areas to a high gloss with the buffer set at 1500 rpm. After buffing, apply glaze, then wax the entire panel.

Runs

A run is caused by too much paint. If more paint is applied to a surface than can adhere, the excess paint will tend to sag and run off the panel. A run in clearcoat can be scraped off with a razor blade or a file-like run removal tool called a nib file. A run can also be sanded out. **Figure 32-38** shows a clearcoat run.

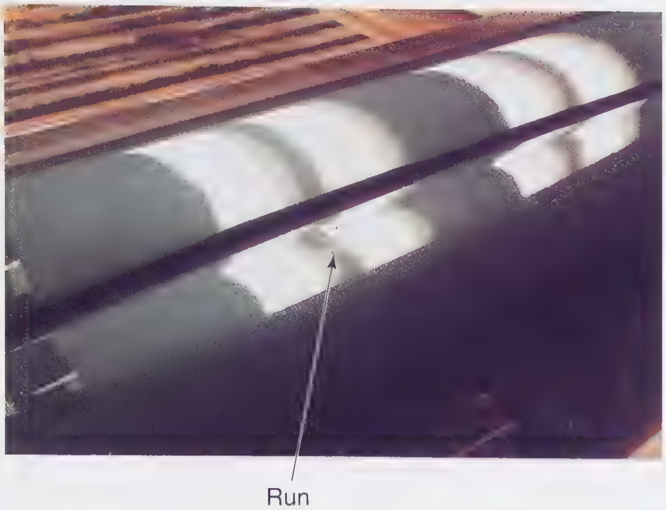


Figure 32-38. *This clearcoat run can be removed after the clearcoat has cured.*

Allow the clearcoat to dry overnight before attempting to remove the run. Trying to scrape off a run in soft paint can worsen the problem.

Figure 32-39 shows a run removal tool being used to scrape off a run. Position the tool's blade perpendicular to panel when scraping off the run. Scrape with a smooth motion. A choppy motion will make ragged edges. Scrape the run until it is level with the surrounding clearcoat. All traces of the run should be removed by scraping. The area can then be color sanded, compounded, polished, glazed, and waxed.

When sanding out a run, sand only on the run. Avoid sanding on the clearcoat around the run. Sanding on the surrounding clearcoat will dig a trough. **Figure 32-40** shows a squeegee wrapped with 1000-grit sandpaper. The squeegee, held on edge, keeps the abrasive sanding action focused on the run and away from the surrounding clearcoat. This is a tedious way to remove a run, but it does work. When the run is level with the surrounding clearcoat, color sand the area with 1500-grit sandpaper and then compound, polish, glaze, and wax.

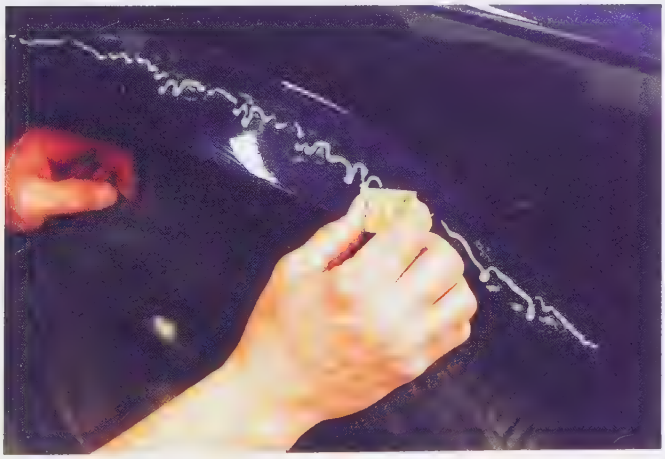


Figure 32-39. *A run removal tool is used to scrape off a clearcoat run. Scrape on the run and not the surrounding clearcoat.*

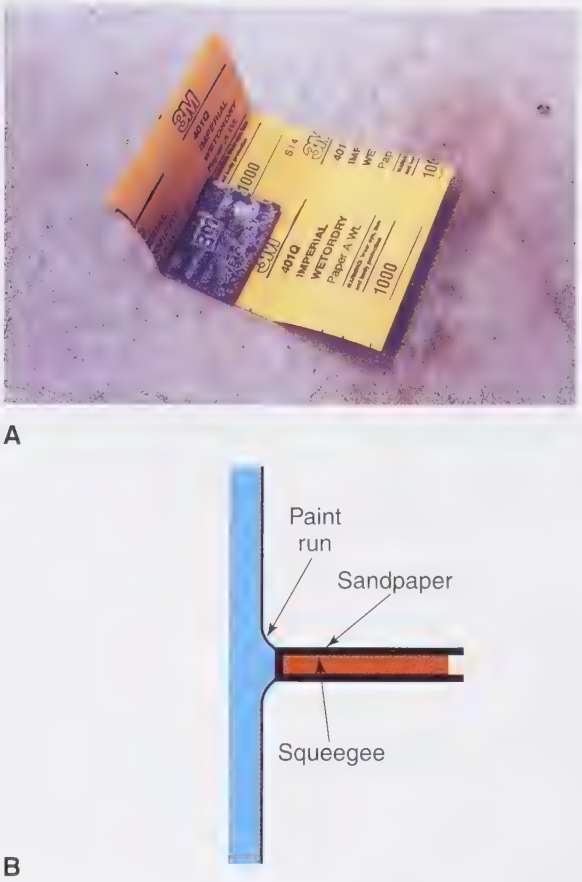


Figure 32-40. *A—Sandpaper is wrapped around a squeegee. Sanding with the narrow edge of the squeegee will concentrate the sanding action on the run and not the surrounding clearcoat. B—Position the squeegee so only the narrow edge will contact the run.*

Scratches

Shallow scratches can be color sanded and buffed out of the clearcoat. **Figure 32-41** shows how to determine if a scratch can be sanded and buffed out. Simply drag your fingernail across the scratch. If the fingernail catches the scratch, then it is too deep to be buffed out. If your fingernail does not catch the scratch, it can be color sanded with 2000-grit sandpaper and buffed out.

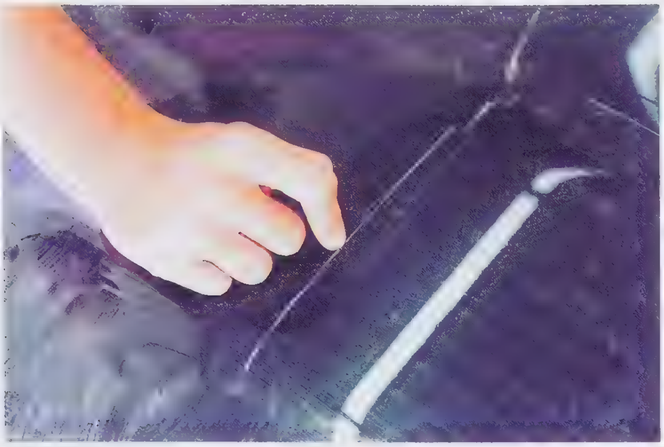


Figure 32-41. *If the fingernail gets caught in the scratch, the scratch is too deep to be sanded and buffed out.*

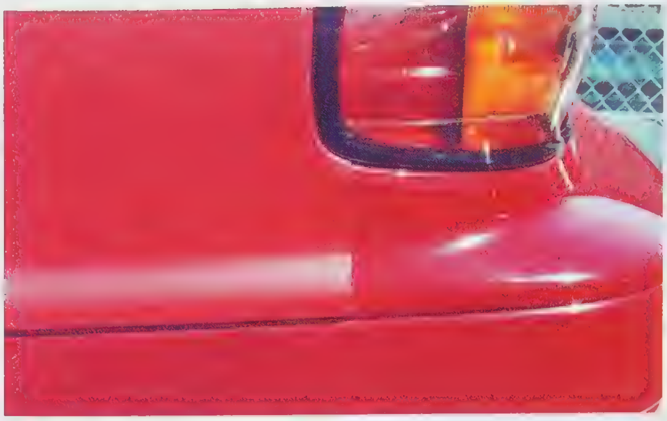


Figure 32-42. *The red paint on this quarter panel is faded. Buffing with compound, polish, glaze, and wax can bring back the shine.*

Fade

Faded single-stage paint has no shine; it looks chalky or dull. However, it can be buffed to bring back the shine. **Figure 32-42** shows an example of faded paint. Minor fading does not require color sanding. Follow the procedures of using compound, polish, glaze, and wax. However, there is only so much paint on the vehicle. Typically, a vehicle from the factory will have between 4–7 mils of single-stage paint thickness. Do not buff off more paint than is necessary to bring back the shine.

Acid Rain

The pH of rainwater is 5.6. Rain in industrial areas has a lower, more acidic, pH because of air pollution. This is ***acid rain*** and it will eat away the paint surface and cause pits. Acid rain damage is repaired by buffing, color sanding and buffing, or repainting. If the pits are so deep that sanding and buffing will remove so much clearcoat that the remaining clearcoat is too thin to protect the underlying basecoat, the panels must be repainted. See **Figure 32-43**.

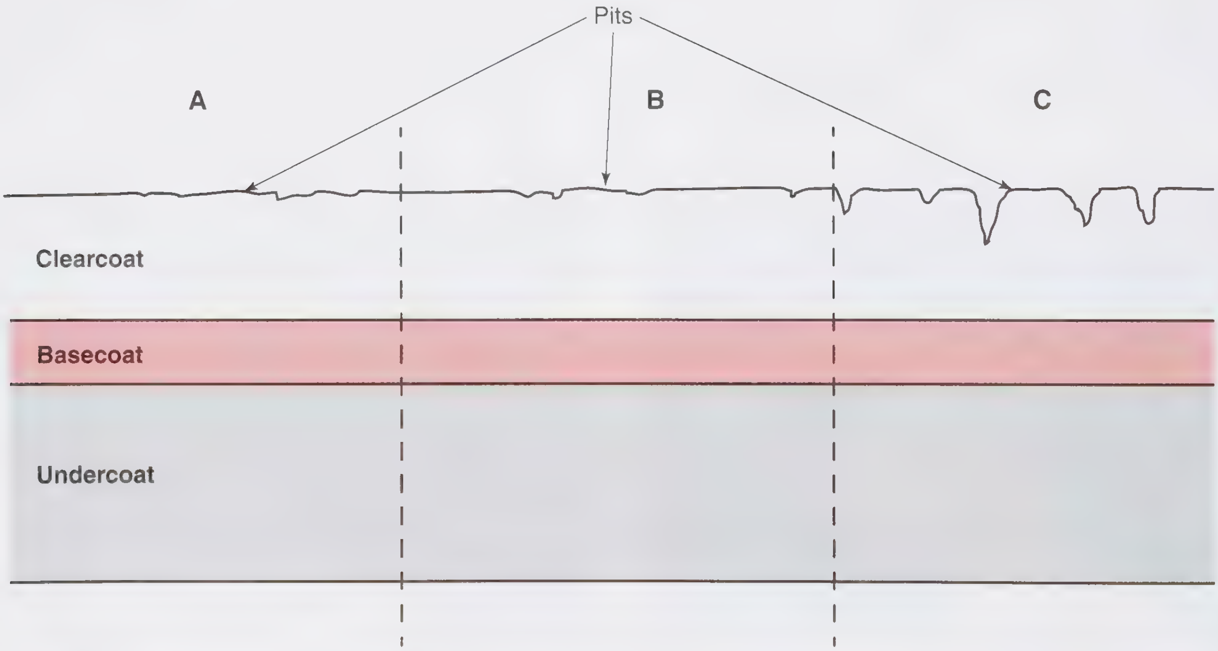


Figure 32-43. *Acid rain damage. A—Minor pits can be buffed out. B—These pits can be sanded with 2000-grit sandpaper and removed by buffing with enough clearcoat remaining to protect the basecoat. C—Sanding out these pits and buffing would remove so much clearcoat that the basecoat would not be protected.*

To remove acid rain contamination, rinse the vehicle with a baking soda wash. This will neutralize any acid on the paint. After hosing off the baking soda, use compound to remove the pits. If this procedure does not work, color sand the surface with 2000-grit sandpaper. If color sanding does not make the surface smooth, the panel must be sanded and clearcoated.

Chips

Small chips (less than 1/4" diameter) in solid colors can be filled with paint. Chips in metallic and pearl colors can also be touched up. However, because the basecoat is not atomized during application, the paint tends to be too dark when applied to the chip. Once the paint dries, the filled area can be lightly sanded and buffed.

Clean the chip and the surrounding area with wax-and-grease remover. Lightly sand the chip and the surrounding area with 2000-grit sandpaper. Mix the appropriate basecoat and add basecoat hardener. Use a small brush or a paper match to apply enough basecoat to completely fill the chip. After allowing the basecoat to cure, color sand the basecoat in the chip to be level with the surrounding paint. Buff the paint to remove the 2000-grit sand scratches.

Summary

- Detailing is done at the end of the painting process before the vehicle is delivered to the customer.
- Color sanding and buffing are the most important aspects of the paint detailing process.
- Always start with the least aggressive sandpaper that will do the job.
- Buffing can remove surface defects such as single-stage fade, runs, orange peel, dirt, scratches, and acid rain.
- Buffing consists of compounding and polishing. Keep the buffer moving and apply light pressure. Avoid the edges.
- Clearcoat has a specific buffing window when buffing is easier.
- Glazing is used to remove swirl marks. Either glaze by hand or by machine.
- Paintless dent repair can remove small dents without requiring repainting.
- Paintless dent repair requires specialized tools and access to the back of the panel.
- Paintless dent repair gradually pushes out the dent.
- Stripes can be painted on or taped on pinstripes.
- Body side molding can be clipped on or riveted on.
- Stripes and small decals are installed dry. Large decals are installed wet.
- Overspray on painted surfaces can be color sanded and buffed.

Review Questions

Please do not write in this textbook. Place your answer on a separate sheet of paper.

1. Sanding before buffing is called ______.
2. When sanding before buffing, always start with the most aggressive method first. True or False?
3. Which is more aggressive, polish or compound?
4. Explain the phrase *buffing window.*
5. Compounding involves the use of an aggressive pad and a coarse abrasive to quickly remove paint defects such as sand scratches. True or False?
6. Buffing pads can be made out of ______ or ______.
7. Buffing technique is a balance of downward hand pressure on the buffer, buffer travel speed, and pad rotation speed. True or False?
8. The two problems to avoid when buffing are ______ and ______.
9. As long as you keep the buffer moving across the surface and there is compound or polish on the pad, ______ are unlikely.
10. After compounding, the paint surface should be buffed with ______ to remove swirl marks.
11. Glazing follows polishing. Glazing fills in the tiny scratches left by the abrasives in the polish. Unfortunately, the glaze will evaporate or wash off soon after being applied. What is the final step that must always follow glazing?
12. If the paint in the dent is cracked or chipped, the dent should not be fixed using paintless dent repair. True or False?
13. Hail damage on a hood created several dents between 1" and 2". Is this vehicle a good candidate for paintless dent repair?
14. There are two ways to remove a dent in the paintless dent repair system. They are the ______ method, and the ______ method.
15. The body side molding on a vehicle has been damaged and needs replacing. Instead of welding on new rivets, most shops install the molding clips with ______ and ______.
16. Explain how to remove an air bubble trapped under a decal.
17. If a glued-on molding is not stretched tight during installation, what problem can occur?
18. Explain how to remove excessive orange peel.

19. When used with a lubricant, a clay bar will pull out and hold onto contaminants that soap-and-water washing cannot remove. True or False?
20. Shallow scratches can be buffed out of a clearcoat. What is a scratch test and what does it tell you?
21. Clearcoat runs can be removed by ______ and ______.
22. The first step in repairing acid rain damage is a(n) ______ wash.
23. A vehicle comes into your shop with minor paint fade. It has a single-stage finish. To bring back the shine, what would you do first?

ASE-Type Questions

1. All of the following are steps in detailing EXCEPT:
   (A) compounding.
   (B) polishing.
   (C) grinding.
   (D) glazing.
2. A clearcoat needs to be color sanded. Technician A wants to use dry sandpaper. Technician B wants to use wet sandpaper. Who is right?
   (A) A only.
   (B) B only.
   (C) Both A and B.
   (D) Neither A nor B.
3. A metal backed glued-on molding is bent during removal. Technician A wants to replace the molding. Technician B wants to grind off the metal backing. Who is right?
   (A) A only.
   (B) B only.
   (C) Both A and B.
   (D) Neither A nor B.
4. Which of the following can be used as a guide when installing a glued-on molding?
   (A) String.
   (B) Wire.
   (C) Masking tape.
   (D) All of the above.
5. A large decal, the same size as a panel, should be installed with ______.
   (A) thinner
   (B) water
   (C) reducer
   (D) wax-and-grease remover
6. A windshield has overspray. Technician A wants to remove the overspray with a razor blade. Technician B wants to remove the overspray with lacquer thinner. Who is right?
   (A) A only.
   (B) B only.
   (C) Both A and B.
   (D) Neither A nor B.
7. A clearcoat has excessive orange peel. Technician A wants to wet sand with 1000-grit sandpaper and then buff. Technician B wants to dry sand using 800-grit dry sandpaper and buff. Who is right?
   (A) A only.
   (B) B only.
   (C) Both A and B.
   (D) Neither A nor B.
8. All of the following can be removed by color sanding and buffing EXCEPT:
   (A) orange peel.
   (B) dirt.
   (C) runs in the clearcoat.
   (D) runs in the basecoat.
9. A scratch in clearcoat is deep enough to catch a fingernail when the fingernail is drawn across it. Technician A wants to color sand and buff the scratch out. Technician B wants to sand and repaint. Who is right?
   (A) A only.
   (B) B only.
   (C) Both A and B.
   (D) Neither A nor B.
10. Acid rain contamination looks like ______.
   (A) pits
   (B) chalk
   (C) bubbles
   (D) blisters
11. The buffing window for a particular clearcoat is eight to thirty-six hours after spraying. Technician A says that the clearcoat cannot be buffed during this time. Technician B says that the clearcoat should be buffed during this time. Who is right?
   (A) A only.
   (B) B only.
   (C) Both A and B.
   (D) Neither A nor B.
12. Technician A says that compound is coarser than polish. Technician B says that glaze eliminates swirl marks. Who is right?
   (A) A only.
   (B) B only.
   (C) Both A and B.
   (D) Neither A nor B.
13. When buffing an edge, the topcoat is removed, exposing the undercoat. This problem is called ______.
   (A) burn
   (B) rub through
   (C) run
   (D) swirl mark

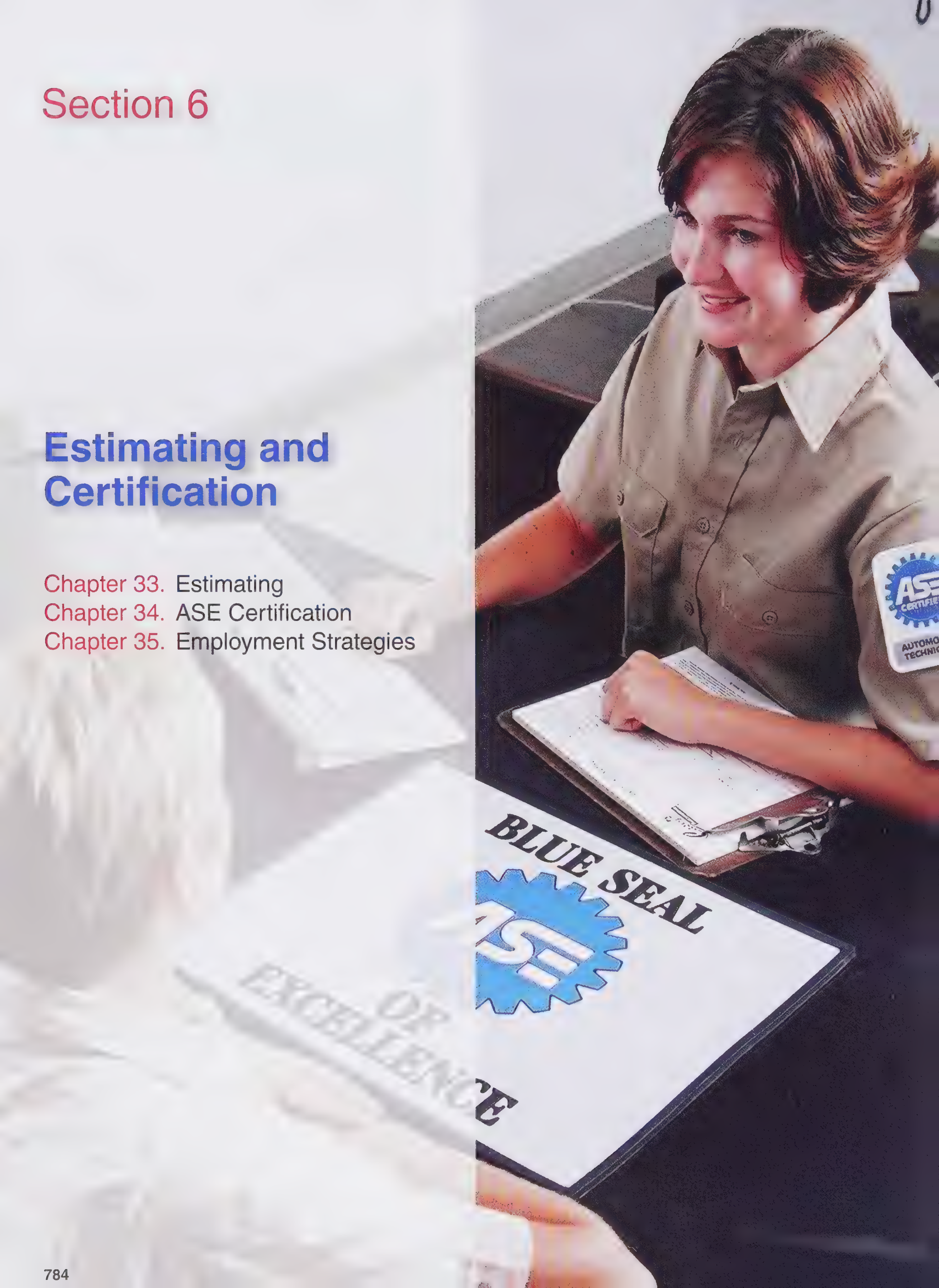
14. A hood is to be buffed. Technician A wants to apply compound to the hood and buff the entire hood at one time. Technician B wants to divide the hood into sections and work one section at a time. Who is right?
    (A) A only.
    (B) B only.
    (C) Both A and B.
    (D) Neither A nor B.

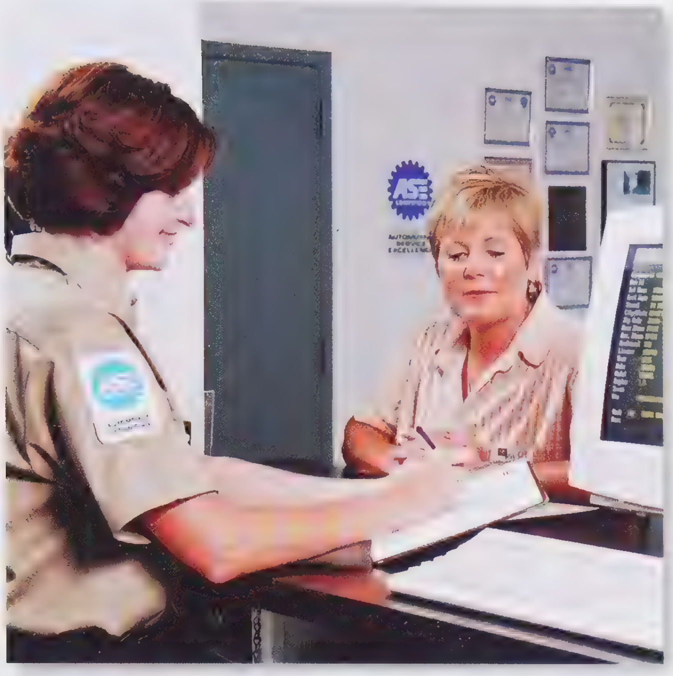
15. Two technicians are discussing paintless dent repair. Technician A says that leverage is required to work out the dent. Technician B says that positioning a light will help to locate the dent. Who is right?
    (A) A only.
    (B) B only.
    (C) Both A and B.
    (D) Neither A nor B.

Section 6

Estimating and Certification

Chapter 33. Estimating
Chapter 34. ASE Certification
Chapter 35. Employment Strategies


BLUE SEAL
OF
EXCELLENCE
ASE



Chapter 33

Estimating

Objectives

After studying this chapter, you will be able to:

- Understand the importance of customer relations.
- Understand the terminology used in estimate writing.
- Know how to check a vehicle for damage.
- List part sources.
- Know how to find out what is included and not included in labor allowances.
- Know how to calculate judgment times.
- Identify the parts of handwritten and computer-generated estimates.

Technical Terms

additional charges
aftermarket parts
assemblies
betterment
comprehensive claim
core charge
estimate
factors
flat rate labor allowance
flat rate manual
judgment labor allowance
liability claim
loss
original equipment manufacturer parts (OEM)
overlap
paint code
prevailing area wage
price fixing
recycled parts
remanufactured parts
torque to yield
trim code
used parts
vehicle identification number (VIN)

Introduction

This chapter will show you how an estimate is written. An ***estimate*** is a detailed plan of action; it is a blueprint for the repair of a damaged vehicle. All body repairs start with an estimate. The repair or replacement of all damaged parts, their cost, and the labor time involved are listed in the estimate. Estimates are subjective; two shops may evaluate the same vehicle and arrive at different repair totals and may even specify different repair parts. This chapter begins with an emphasis on customer relations and the relationship between body shops and insurance companies. The different types of damage, how it is inspected, and how this damage is repaired are important components of this chapter, and are covered in detail.

A body shop's survival depends on its ability to turn a profit. Topics covered in this chapter, such as labor, part prices, and additional charges, are critical to understanding what it takes to write an effective estimate. Therefore, the chapter ends with examples of estimate writing. How to calculate judgment labor allowance, a topic that is often misunderstood, is addressed as well. You may not be required to write estimates in your collision repair job, but you must be able to read and understand them.

Role of the Estimator

The estimator is a vital and arguably the most important employee in the shop. The estimator must write an estimate that is low enough to convince the customer to bring the damaged vehicle in for repair, yet high enough for the shop to make a profit. All collision repairs start with an estimate. Writing a well-founded estimate requires a good eye and a thorough knowledge of body repair. Perhaps the most important aspect of writing an estimate is the ability to quickly establish a friendly bond with the customer.

Working with the Customer

An estimator must have good people skills, as the estimator deals directly with the potential customer. Often, the estimator is the only shop employee who talks to the customer before the repair begins. Just as often, the customer's choice of shop is determined by the impression created by the estimator.

The first step in writing the estimate is to greet customers and thank them for bringing the vehicle in for an estimate. Obtain the customer's name, address, phone numbers, e-mail address, and insurance company information. Ask the customers if they would like to be present as the estimate is written. Some body shops have waiting rooms for customers. If not, the customer must wait in the office or watch as the estimator examines the vehicle. Always treat the customer, the vehicle, and the vehicle's contents with respect. The customer will notice the kind of care you give the vehicle. Never put a foot on the bumper or lean against the car. If contents must be removed for inspection, always put them back where they were found. Taking a vehicle in for repair may be a major disruption in the life of the customer. Be polite. Be respectful to the customer, and it is likely that the customer will be respectful to you.

Examine the damage carefully and ask the customer about the collision. Knowing the details will help you locate all the damage. If your customer is interested, take the time to explain the repair process. Point out the panels that will be repaired or replaced, and explain how much repair time is involved. Explain the shop's standards and why your shop is their best choice for the job. The estimator has to *sell* the repair to the customer. This is the heart of the process. A shop stays in business by repairing vehicles, not by writing estimates.

Go over each line of the estimate with the customer. Some customers will only be interested in the dollar total, so it may be necessary to explain how your shop is the best choice. However, the customer should be given the opportunity to ask questions about the estimate. Tell the customers when the vehicle can be brought in for repair and how long the repair process will take. Ask the customers if there are any questions, and remind them to contact you if they think of questions after leaving the shop. Finally, thank the customer again for bringing the vehicle in for an estimate.

Working with Insurance Companies

Damage to a vehicle is called a ***loss*** by an insurance company. An insurance company may pay for the repair of a damaged vehicle. This is called a claim. See **Figure 33-1** for a list of commonly used insurance company terms. There are two ways an insurance company can be involved in a claim. In the first case, the insured vehicle owner damages another vehicle. This is a ***liability claim***. The insurance company will pay to repair the damage caused by the insured. In the second case, the insured owner's vehicle is damaged, either in a collision or by a calamity such as hail or vandalism. This is called a ***comprehensive claim***.

An insurance company may employ estimators to write estimates and adjusters to manage the claim process. Other insurance companies use estimator/adjusters who perform both tasks.

Insurance Company Terms

Insurance policy. An agreement between an individual and an insurance company.

Loss. Damage to a vehicle.

Claim. A customer has incurred a loss or caused a loss and the insurance company will pay for repair or replacement of the vehicle according to the terms in the insurance policy.

Total loss. The cost of repairing a vehicle exceeds the value of the vehicle; the insurance company pays the owner the value of the vehicle and closes the claim.

Prior damage. An unrepaired loss that is part of the current claim.

Unrelated prior damage. An unrepaired loss that is not part of the current claim.

Estimator. The person who locates all the damage, decides on what parts will be repaired or replaced, and calculates the cost of the repair.

Adjuster. The insurance company employee who administers the paying of the claim.

Insured. The individual named in the insurance policy.

Pre-accident condition. The appearance and wear the vehicle had before a loss.

Liability coverage. An insurance policy that will pay for damages caused by the insured to other people's property.

Comprehensive coverage. An insurance policy that will pay for damages to the insured vehicle.

Betterment. When the repair of a loss makes the vehicle better than it was before the loss.

Figure 33-1. *These insurance company terms are used throughout the body repair industry. Read and understand them.*

The insurance company may ask the vehicle owner to drive the damaged vehicle to at least three body shops for estimates. The vehicle owner is doing comparison shopping for the insurance company. The owner submits three estimates to the insurance company, and the insurance company will choose a body shop. Typically, an insurance company instructs the owner to have the vehicle repaired by the shop with the lowest estimate.

In some cases, the vehicle owner may be instructed to take the damaged vehicle to a drive-in claims office. There, insurance company employees examine the vehicle, take digital photos, and prepare an estimate. The insurance company may also maintain a list of approved body shops. To be approved, a body shop must have trained employees using the proper equipment. If the vehicle owner decides to have the vehicle repaired at an approved body shop, the insurance company may offer a warranty on the repair. In a similar scenario, the insurance company will send out an estimator/adjuster to examine the damaged vehicle at a location convenient to the vehicle owner. The mobile estimator/adjuster enters data into a laptop computer and prints out an estimate.

Some insurance companies have a direct repair arrangement with one or more body shops. This arrangement does not require that the vehicle owner get estimates from several shops; the direct repair body shop estimate is all that is required. The insurance company informs the vehicle owner to go to a particular direct repair body shop, and the shop bills the insurance company after the repair is made. The arrangement between the insurance company and the body shop requires that the body shop fulfill several requirements. These requirements include properly trained employees, adequate equipment, acceptable labor rate, use of the lowest cost parts available, timely repair, and a warranty on repairs. The insurance company periodically checks on each direct repair body shop to monitor compliance with the requirements.

If a damaged vehicle cannot be driven, it is generally towed from the scene of the crash to a storage lot or body shop. If the vehicle is in a storage lot, it will need to be towed again once it is decided which body shop will make the repairs. The body shop may write the estimate or the insurance company may send out a mobile estimator/adjuster. (If the body shop is a direct repair shop, the requirements may state that the repairs must begin within two days from the day the vehicle was towed to the shop.)

Identifying Damage

A customer looks at the mangled vehicle and sees only the obvious surface damage. A skilled estimator sees this and much more. An experienced estimator is intimately familiar with what is underneath the visible damage and knows how much time, effort, and skill is needed to repair the damage, or if it is even worth repairing. Knowing what to look for comes from experience in collision repair. Knowledge of what really happens to a vehicle involved in a collision and knowing what it will take to repair the damage are important qualities for an estimator.

Vehicle damage can be classified as follows:

- cosmetic
- panel
- structural
- mechanical
- nondriveable

Scrapes and scratches in paint are cosmetic damage. Panel damage is a step up in severity and includes dents or even tears in outer panels such as fenders, bumpers, and doors. The damage may be repairable or may require panel replacement. In panel damage, the supporting structures beneath the outer panels are not affected.

Structural damage means that the supporting structures, as well as the outer panels, are moved out of position, bent, crushed, or dented. Structural panels include the radiator support, frame rails, and center pillar. See **Figure 33-2**. Damaged structural parts may be repaired or replaced.

Bent steering linkage or a punctured radiator are examples of mechanical damage. In most cases, damaged mechanical parts are replaced and not repaired. Structural and/or mechanical damage will render the vehicle nondriveable. For example, a vehicle may be nondriveable due to a bent McPherson strut and lower control arm. A nondriveable vehicle must be towed.

Walk around and inspect the entire vehicle before focusing on the damaged area. Check to see if the vehicle is sagging at one corner. Look down the side of the vehicle to identify any panel or wheel misalignment. On pickup trucks, sight the top of the tailgate into the bottom of the rear window. If the two are not parallel, then suspect frame damage. See **Figure 33-3**. Look at the wheels. They should stand straight and be at the center of the wheel opening. Suspect damage if there is any deviation. Suspension or frame damage may cause a wheel to be pushed backward, forward, in at the top, or out at the top.

Examine panel gaps. Uneven gaps mean that something is out of alignment. **Figure 33-4** shows an uneven panel gap. Look at the deck lid, door, and hood gaps, even on the nonimpact side. Check the roof above the pillars for inertia damage. If the rear of the vehicle kicks up during a front-end collision, the roof will have buckles at the pillars. Check the gap between

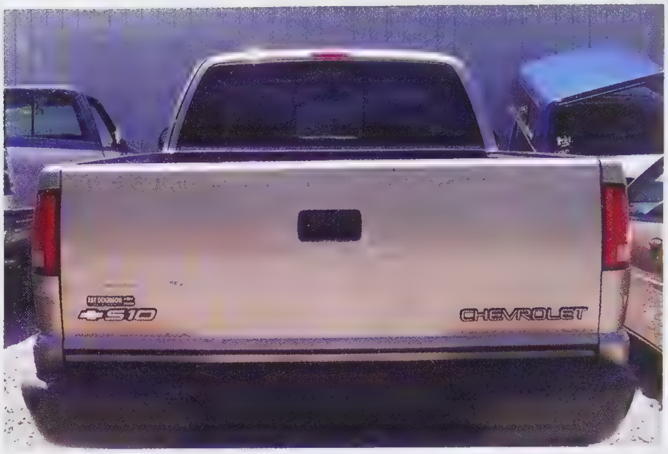


Figure 33-3. *This pickup truck exhibits "twist." Notice how the top of the tailgate is not level with the bottom of the rear window.*

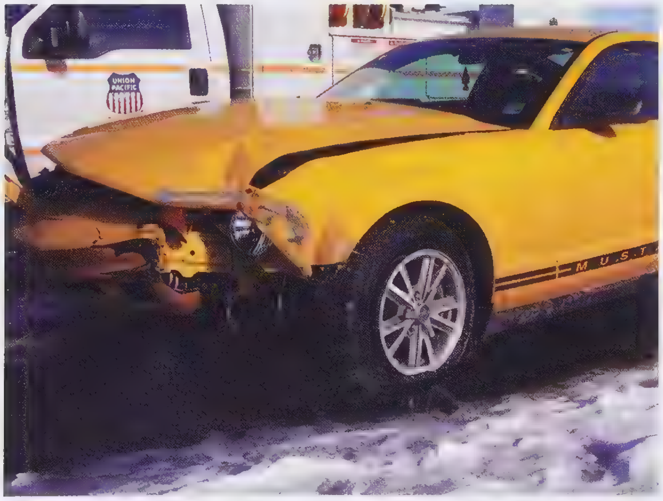


Figure 33-2. *Structural damage. This unibody vehicle has sidesway on the front section as well as damage to the hood, fender, bumper assembly, and wheel.*

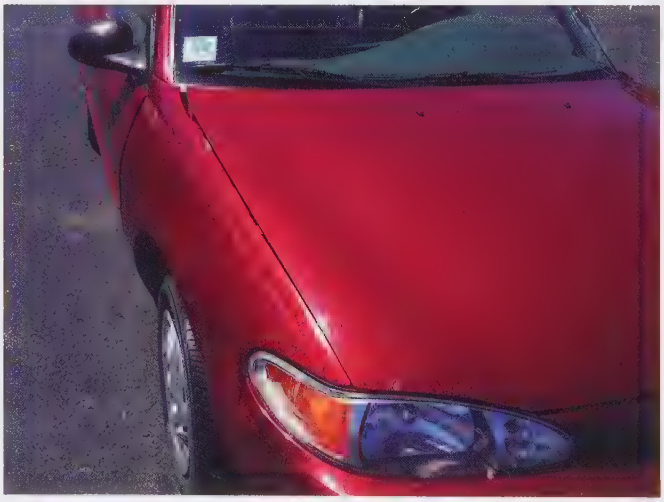


Figure 33-4. *This unibody vehicle took a hard hit in the left center pillar (driver's side). The hood/right fender gap is not even.*

the bed and the cab on pickup trucks. Look at the door/fender gap. If the gap is wide at the top and narrow at the bottom, suspect that the front end has sag damage. If the gap is narrow at the top and wide at the bottom, suspect that the front end has kickup damage. Also, look under the vehicle for signs of leaking oil or coolant.

Open the hood and check for damage. Make an x-check in the engine compartment. Suspect unibody or frame damage if the measurement is not within specification. During the rapid deceleration of a collision, the weight of the drive train may cause motor mounts and brackets to bend. Look for bends in the mounts or a shift in the mounting location. A side hit on front-wheel-drive (FWD) vehicles can bend engine pulleys in the same way a front hit affects the front of an engine on rear-wheel-drive (RWD) vehicle. Look closely at all parts of the engine for misalignment or leaking fluids. See **Figure 33-5**. When inspecting a front-hit vehicle, check the headlights, license plate bracket, and grille to see if they are loose. Loose parts have broken mounting tabs and should be replaced. The mounting tabs can also be broken off the condenser and radiator; check these components for looseness.

On a front-hit vehicle, check to see if the A/C system is still pressurized. If the A/C system does not hold pressure, the system has a leak somewhere. A hole in the A/C condenser or lines will allow the refrigerant to leak out and be replaced with air. Moisture in the air will ruin the accumulator or receiver/drier. If the A/C system has no pressure when the estimate is written, add a new accumulator or receiver/drier to the estimate. If the A/C system is still pressurized, check the condenser fins. Flattened fins can be straightened.

Some suspension fasteners are designed for one use only and are called ***torque to yield*** bolts. They stretch when tightened to the proper torque. When this type of bolt is removed, it must be thrown away and replaced with a new, unused bolt. Replacement of torque to yield bolts should be charged to the customer. Plastic pushpins are usually single-use. If a fender liner or door trim panel is removed, add the cost for new plastic pushpins. If a hood emissions system sticker or A/C system sticker is lost when the part it is attached to is replaced, the estimate must include sticker replacement. Also, if a truck topper or cap is removed during repair, add the cost of new foam weatherstrip tape because the topper cannot be removed without ruining the existing weatherstrip tape.

Check the interior for damage and look at the air bags. Collision estimating guides list the parts that must be replaced or inspected after air bag deployment. Check the list to be sure that all required components are added to the estimate.

Always suspect hidden damage when you study the damaged area. Examine anything the damaged part is attached to or welded to. Steel parts can yield and shift back after a collision. Damage under the outer panels may be worse than what appears on the surface. Vehicles with plastic body panels have an even greater possibility of covering up hidden damage because deformed plastic returns to its original shape after impact more readily than steel. Look for cracked undercoating, split seams, and cracks in the surface rust on suspension parts, **Figure 33-6**. Parts can be knocked off during a crash. Always check for missing wheel covers, trim rings, marker lights, and license plates. Be sure to take note of missing parts.

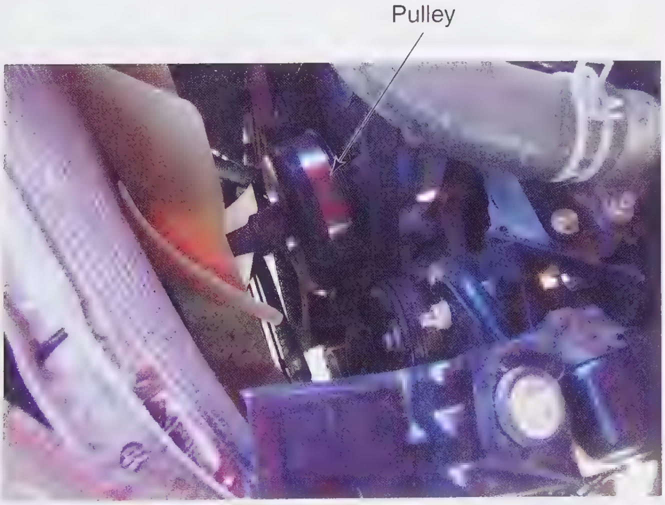


Figure 33-5. *The pulley is bent down on this front-hit vehicle.*

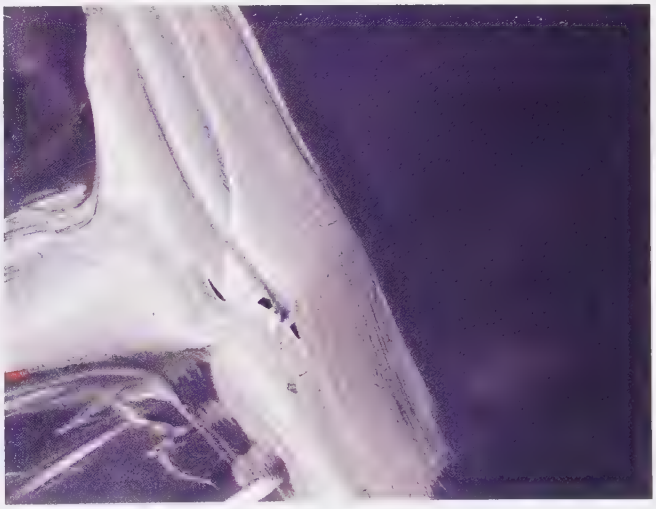


Figure 33-6. *The force of a rear hit caused this trunk floor seam to separate on this unibody vehicle.*

The vehicle should be raised on a lift or the estimator should crawl under the car if a unibody vehicle bumper reinforcement is moved, bent, or buckled (unirails attached to bumper reinforcement have been moved or buckled); a door is out at the top (the cowl or center pillar has moved, check for damage to the rocker panel from underneath); a full-frame bumper is moved or hit at frame rail or hit hard between rails (frame rails have moved); the tailgate top is not level with the bottom of the rear window (frame has a twist); the door/fender gap is not even (front of vehicle is high or low); a wheel is moved forward or rearward or in or out at top (suspension or frame damage, check all steering and suspension components and the engine cradle); fluids are leaking (check for cracks in radiator, condenser, transmission case, engine block, or oil filter); or air bags are deployed (hard hit, sudden stop). The vehicle does not need to be raised up on a lift for inspection if none of these conditions are present.

While under the vehicle, search for cracks in undercoat or sealer; buckles, bends or bulges in the frame or unibody; misalignment of parts; disruption of the surface rust pattern on suspension parts; tilted rubber isolators; and leaking fluid. If frame or unibody damage is discovered, measure the damage by making x-checks under the front, center, and rear sections of the vehicle. Determine if the frame or unibody has diamond, twist, kickup, sag, mash, or sidesway damage. While the vehicle is on the lift, rotate the wheels to see if they wobble while turning.

Check for binding or looseness in a steering system by turning the steering wheel. Center the steering wheel by turning the wheel all the way clockwise. While counting the number of turns, turn the steering wheel all the way back in the opposite direction. Divide the number of turns by two then turn the wheel that number of turns. If the wheels point straight ahead, the steering wheel is centered. If the front wheels are not pointing straight ahead, suspect steering arm damage. If the steering wheel is not centered, suspect steering gear box or rack-and-pinion damage. With the vehicle on the ground and the steering wheel centered, bounce the front of the car. If the steering wheel turns, the vehicle has bump steer, which is caused by an out-of-level condition in the rack-and-pinion assembly or the steering linkage. **Figure 33-7** is a quick check guide for estimators.

NOTE

The repair cost of a total loss vehicle is close to or exceeds the value of the vehicle. The amount of damage required to declare a damaged vehicle a total loss depends on the value of the vehicle. An older vehicle, which is not worth much, may be totaled due to something as minor as cosmetic damage.

Estimator Quick Checks—Chart A
Walk around the vehicle from a distance.
Are the wheels in the right place in the wheel opening? Is the vehicle leaning in one direction? Are fluids leaking from the vehicle? Are the panel gaps—hood/fender, fender/door, front door/rear door, door/quarter panel, deck lid/quarter panel or bed/cab—even?
For pickup trucks, view the truck from the rear.
Is the top of the tailgate level with the bottom of the rear window?
Look inside the vehicle.
Are the air bags deployed? Does the steering column look straight? Are the seat belts hyperextended?
Look at the damage.
Evaluate every part welded or attached to the damaged part.

(Continued)

Figure 33-7. *This chart summarizes estimator quick checks. Make these checks on every vehicle.*

Checklist—Chart B		
Observation or Condition	**Check These, Replace If Damaged**	**Replace or Repair**
No pressure in A/C system	Condenser and lines for holes	Receiver/drier or accumulator
FWD/AWD front wheel in at top	Rack and pinion, tie rod	Strut
FWD/AWD front wheel out at top or pushed forward or rearward	Rack and pinion, tie rod, engine cradle, drive axle, stabilizer bar, lower frame rail	Strut, lower control arm, steering knuckle
LASA front wheel in at top	Spindle, (steering knuckle on 4WD)	Upper control arm
LASA front wheel out at top or pushed forward or rearward	Stabilizer bar, upper control arm	Lower control arm, spindle, (steering knuckle on 4WD)
RWD front hit and radiator support is moved back	Condenser, radiator, fan, fan clutch, fan shroud, water pump, battery	
FWD hit on side near engine pulleys	All engine pulleys	
Underneath	Oil pan, transmission pan, gas tank, brake lines, gas line	
Air bag(s) deployed	Check CEG or manual to determine what must be inspected and what must be replaced	
Door/fender gap wide at top, narrow at bottom	Radiator support, apron, upper rail	Kickup damage in lower rail
Hood/fender gap wide at one front corner, narrow at other front corner	Radiator support, upper frame rail, lower frame rail	Sidesway damage on upper and/or lower rails
Rear edge of hood pushed against windshield or cowl vent panel	Windshield for cracks, cowl	Mash damage on upper and/or lower rails
Front door out at top	Rocker panel, firewall	Sidesway damage at cowl
Rear door out at top	Rocker panel, floor	Sidesway damage at center pillar
Front door drops when opened	Center pillar	Mash damage on upper and/or lower frame rails causing tipped cowl
Gap between cab/bed tight on one side, wide on the other (pickup truck)		Diamond or sidesway
Top of tailgate not level with bottom of rear window (pickup truck)		Twist
Gap between cab/bed not even tight or wide at top and the opposite at the bottom		Twist, sag, kickup

Figure 33-7. *Continued.*

Specifying Repair Procedures

The estimator must understand all the steps needed to return the vehicle to pre-accident condition. This includes both bodywork and mechanical repairs. It is not necessary for the estimator to be able to do each step. However, the estimator must know what repair steps are necessary. Various repair procedures with individual steps are listed in **Figure 33-8**. Each step must be identified and the appropriate charges made for the shop to make a profit.

Abbreviations are used to indicate what procedure will be followed during the repair. R&I means to remove and install the same part back on the vehicle.

Common Steps in Automotive Collision Repair

Panel repair

- Examine the damage
- Plan the repair
- Protect the vehicle
- Remove the obstructions
- Rough out the damage
- Remove the paint
- Mix, apply, and cure the filler
- Sand the filler
- Replace the obstructions after painting

Bolted panel replacement

- Examine the damage
- Plan the repair
- Remove the obstructions
- Unbolt the panel
- Install the new panel
- Align the new panel
- Replace the obstructions after painting

Welded panel replacement

- Examine the damage
- Plan the repair
- Protect the vehicle
- Remove the obstructions
- Cut out the damaged panel
- Rough cut the new panel
- Final cut the new panel
- Prepare the splice joint
- Align the new panel
- Weld the new panel
- Dress welds
- Replace the obstructions after painting

Panel refinish

- Examine the panel
- Plan the repair
- Clean the panel
- Mask the vehicle
- Featheredge
- Clean back side of welds
- Mix, spray, and cure primer (including backsides of welds)
- Mix, spray, and cure surfacer
- Block sand surfacer
- Final sand surfacer
- Clean the vehicle, remove masking
- Re-mask the vehicle
- Mix and spray the sealer
- Mix and spray the basecoat
- Mix and spray clearcoat
- Clean spray equipment
- Remove the masking
- Color sand and buff
- Clean the vehicle

Frame repair

- Measure
- Plan the repair
- Remove parts for access
- Mount the vehicle on frame equipment
- Tie the vehicle down
- Hook up pulls
- Pull and spring hammer
- Remeasure
- Remove the vehicle from the frame equipment

Mechanical repair

- Examine the damage
- Plan the repair
- Remove the obstructions
- Remove the part
- Install the new part
- Align and refill new part
- Replace obstructions

Figure 33-8. *Knowledge and understanding of these steps in collision repair will help you write a better estimate.*

For example, a fender is damaged, but the front bumper is not damaged. However, the bumper blocks access to the fender, so the bumper must be removed before the fender can be removed and repaired. In this example, the bumper is taken off, the fender is removed, the repaired fender is bolted back in place, and the bumper is reinstalled on the vehicle.

R&R means to remove and replace a damaged part with a replacement part. Both R&I and R&R include adjusting the part into alignment when it is put on the vehicle. **Figure 33-9** shows R&R of a welded part.

D&R stands for disconnect and reconnect. A good example of D&R occurs when MIG welding on a vehicle. To prevent damage to the vehicle's electrical system, the negative battery cable must be disconnected. When the welding is completed, the battery cable must be reconnected before the vehicle can be started.

The abbreviation O/H means to overhaul a part. An assembly—made of several component parts—is put back together in an overhaul. For example, a chrome bumper assembly may consist of a face bar, turn signals, air dam, upper cover, and fog lamps. The overhaul includes removing the damaged bumper assembly, installing new parts on the new face bar, transferring undamaged parts from the damaged face bar to the new face bar, aligning the assembly on the vehicle, and tightening the bolts. If a new part is installed on an assembly that is overhauled, a separate labor charge cannot be made because installation of the new part is included in the overhaul. Parts that are included in the overhaul are labeled as IOH in collision estimating guides.

The abbreviation *m* stands for mechanical. Mechanical labor is distinct from commonly performed body labor. Examples of mechanical repairs include replacement of water pump, transmission cooler, A/C condenser, and ABS sensor. See **Figure 33-10** for an example of a mechanical repair. The abbreviation *s* represents structural panel labor. Structural panels support the suspension and drive train and protect the passengers. Structural panels are vital for the safety of the vehicle's occupants. Special care is required during the repair or replacement of structural parts.

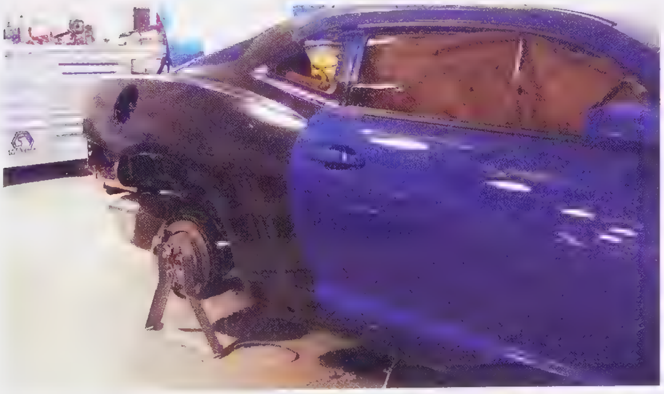


Figure 33-9. *This is R&R of the right quarter panel. The replacement quarter panel is test-fitted to the vehicle after the damaged quarter panel has been removed.*

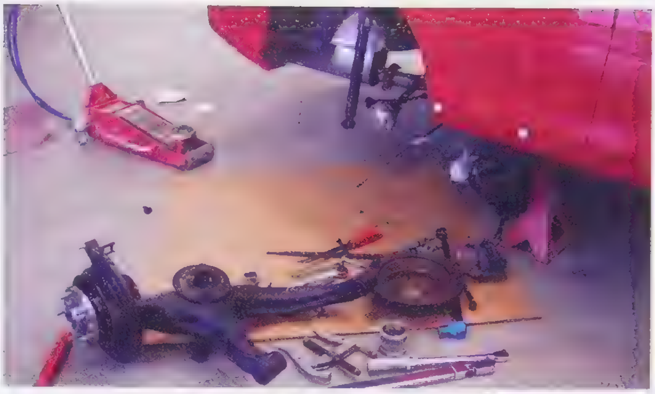


Figure 33-10. *The right rear suspension is being replaced on this vehicle. This is considered a mechanical operation.*

Repair vs. Replace

Deciding whether to repair or replace a damaged part should come only after careful inspection and analysis of the damage. A part that cannot be made safe by repairing must be replaced. If a unirail, which is made of high-strength steel, is kinked and straightening would leave it weakened, the unirail must be replaced.

Another way to determine whether to repair or replace is to compare the cost of repair to the cost of replacement. If the cost of repair is more than 75% of the replacement cost, the damaged part is often replaced. For example, the estimated time required to repair a dented fender is four hours. At a shop labor rate of $50 per hour, the cost of repair would be $200. The cost of a replacement fender is $150, plus two hours labor to install the fender. The total cost of replacement is $250. The repair cost is more than 75% of the replacement cost, so the fender would be replaced rather than repaired.

Easily replaced, low-cost panels such as bolt-on fenders and hoods are often replaced if they have more than minor damage. A damaged aluminum hood is usually replaced because the repair of a damaged aluminum part requires more time and skill than the repair of a steel part. A quarter panel, which is relatively expensive and time-consuming to replace, will generally be repaired even when moderately damaged.

Some damage is not repairable. For example, if the metal is torn in a damaged quarter panel and there is no access to the back of the panel, alignment of the torn edges is not possible. Longitudinal force on a body line may cause two or more buckles to form at a pivot point, such as an internal brace. These buckles, which are referred to as a double fold, are close together. The metal in the double fold is work hardened, both by the panel forming process during manufacture and by the damage itself. When sheet metal is severely damaged in this way, the folds are so hard that straightening would be difficult. Heat could be applied to the folds while pulling, but the customer would be better served by panel replacement. Similarly, internal brace damage is generally not repaired. When internal hood braces are bent, and there are double folds in the metal at the edge of the hood, repair is not practical and the hood should be replaced.

Sourcing Parts

In addition to a strong understanding of collision repair procedures, the estimator must have knowledge of part sources. There are four sources of parts: OEM (original equipment manufacturer), aftermarket manufacturer, salvage yards, and part remanufacturers. New OEM parts are the first choice, followed by good used parts, remanufactured parts, and aftermarket parts. New OEM parts will cost the most. Due to factors such as condition and location of the part, it is impossible to generalize about the cost of used parts.

Original equipment manufacturer parts, or ***OEM parts***, are the same as the parts installed on the vehicle when it was made. A vehicle's manufacturer, such as Ford, is required by law to have a 10-year supply of replacement parts available. Not only will the manufacturer produce extra parts, it will also contract with other manufacturers to make replacement parts for them. These parts must meet the vehicle manufacturer's criteria for fit, thickness, and durability. Most of the time, OEM parts will fit although, as with any manufacturing process, defective parts may occasionally be shipped. OEM parts are sold as single pieces.

Used parts, or ***recycled parts***, are obtained from salvage vehicles. A vehicle that has been declared a total loss will still contain many usable parts. A salvage yard buys the totaled vehicles and sells the usable parts. Used parts may have previous repair damage, such as dents, dings, or rust. Labor time should be allowed to repair this damage. Used mechanical parts, such as McPherson strut assemblies, radiators, and alternators, may have wear due to the age and mileage of the donor vehicle.

Although used parts cost less than OEM parts, used part prices are not standard. The price is set by the salvage yard and determined by the model year of the vehicle and the demand for the part. For example, a fender for a late-model vehicle will cost more than the fender for an older vehicle. Also, a full frame, which is not commonly replaced, may cost less than a door, which is commonly replaced and in demand.

Used parts may be described as LKQ—like kind and quality. LKQ means that when comparing the pre-accident condition of the damaged part to the used part, the used part is not in better or worse condition than the pre-accident condition of the damaged part. For example, a used mechanical part should not have more mileage than the damaged part. For a body part, the used part should not have more rust than the damaged part. LKQ is an obsolete term; *recycled automotive parts* is the preferred terminology. If the insurance company pays for a replacement part that is better than the damaged part, the vehicle owner may be charged ***betterment***. Betterment means that the insurance company will only pay for a part that is as good as, but not better than, the damaged part. For example, a vehicle with worn tires is hit in the left front, requiring the replacement of the left front tire. The new tire is better than the tires on the vehicle. The vehicle owner is charged betterment for the cost difference between the new tire and the cost of a worn tire. The betterment dollar amount is determined by the mileage left in the damaged part. If the damaged tire is nearly worn out, the customer will end up paying nearly all the cost of the new tire.

Used parts are sold as assemblies. For example, if a door is needed, the entire door assembly—hinges, glass, regulator, and trim—is included. **Figure 33-11** shows a used quarter panel assembly. In this example, the right rear corner of an SUV was removed from the donor SUV at the salvage yard. The quarter glass, fender liner, interior panel, and rear frame rail are included in the assembly.

The following are used structural assemblies commonly specified for collision repair:

- Rear section and roof, or a rear clip top. See **Figure 33-12**. This assembly is cut out at the windshield pillar and the floor under the driver's seat or rear seat. It is used to repair a vehicle damaged in the rear or side.
- Rear section or rear clip. This assembly is cut at the sail panel and across the floor in front of the rear seats. It is used to repair a vehicle damaged in the side and rear.
- Front clip. A front clip on a unibody is cut at the windshield post and floor under the front seat. On a full-frame vehicle, the front clip includes the fenders, hood, radiator support, grille, headlights, and bumper. The radiator and A/C condenser may also be included. A front clip is used when structural parts such as the radiator support or upper frame rail are called for.

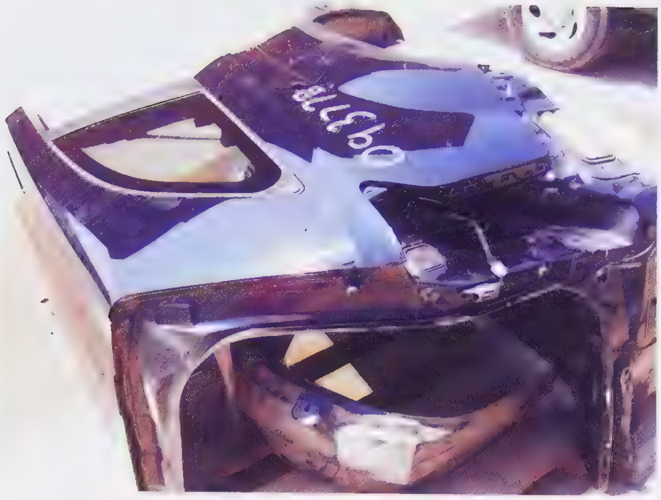


Figure 33-11. *This used quarter panel assembly includes a portion of the roof, rocker panel, and floor as well as the entire quarter panel.*

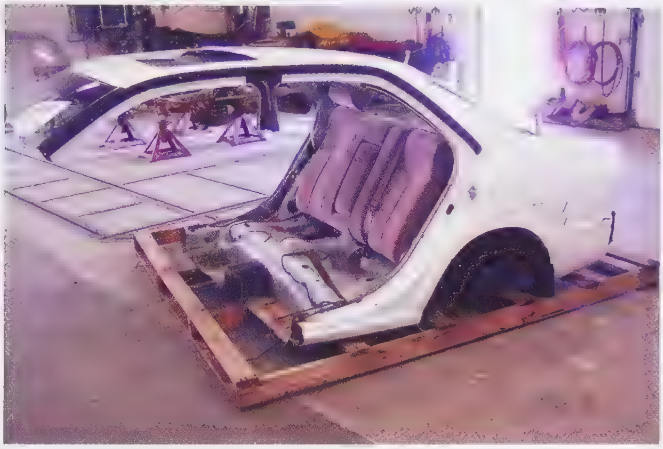


Figure 33-12. *This rear clip top was cut at the windshield pillars and under the rear seat.*

- Side clip. A side clip consists of the rocker panel, center pillar, portions of the A and C pillars, and the doors. It is used to repair a side damaged vehicle.

Mechanical parts may also be recycled. However, some used parts are subject to wear, such as struts, calipers, and disks. Due to the safety risk inherent in reusing a worn part, this may not be the best solution for the customer. However, the insurance company may insist on recycled automotive parts to save money on the claim.

Used parts are rated by their condition. Most used part sales are made over the phone or on the Internet. Salvage yards rate the part with a grade and code to indicate the amount and type of damage, **Figure 33-13**. Location codes indicate where the damage is found on the part. See **Figure 33-14**. An accurate description of the part's condition is essential when pricing a used part.

Aftermarket parts are manufactured by an independent manufacturer, not the one that made the OEM parts. As a rule, these parts cost less than OEM parts. Aftermarket parts have a reputation for being of lower quality than OEM parts. Aftermarket parts may not fit correctly, panel bends may not be as sharp, and panel gaps may be uneven. Some aftermarket parts do not have as many welds as OEM parts. Therefore, the aftermarket part may not be as safe as an OEM part. Depending on their quality, aftermarket parts may or may not fit as well as OEM parts. Extra time may be required to make an aftermarket part fit. Because aftermarket parts cost less than OEM parts, insurance companies may specify the use of less expensive aftermarket parts. In this case, the customer should be allowed to decide if aftermarket parts will be installed on a damaged vehicle. If OEM parts are preferred, the customer must pay the difference in cost between aftermarket parts and OEM parts.

Aftermarket parts also include accessories that the customer has installed on the vehicle, such as running boards, sun visors, taillight covers, and decals. These parts must be repaired or replaced if damaged. Finding the price and source of some aftermarket accessory parts can be difficult. Aftermarket parts are sold individually in the same manner as OEM parts.

Remanufactured parts are damaged or worn parts that have been repaired to OEM specifications. Commonly remanufactured parts include wheels, water pumps, bumper covers, and chrome bumpers. Remanufactured parts are sold individually. For example, a damaged alloy wheel can be replaced with a remanufactured wheel. The body shop orders the correct alloy wheel and returns the damaged wheel to the remanufacturer in the same box the replacement wheel was shipped in. The remanufacturer counts on getting the damaged or worn part back so it can be repaired and resold to another customer. The price of a remanufactured part may include a core charge. The core is the damaged or worn out part. When the core is returned, the ***core charge*** is refunded. Remanufactured parts include a warranty that is comparable to an OEM warranty.

Vehicle Codes

Before estimators can begin sourcing parts, it is critical that they know exactly what vehicle to source parts for. Do not assume you know the year and model just from experience. Year to year differences between models can be subtle. Avoid costly mistakes by first verifying the make, model, and model year of the vehicle before ordering parts.

Damage Grades and Types

Term	Definition
A-Grade	The highest quality part. An A-grade part contains a minimum amount of damage. A-grade parts are less than 1 unit* or less of repair.
B-Grade	The second level of quality for a part. A B-grade part contains a moderate amount of damage. B-grade parts have more than 1 unit of damage, but do not exceed 2 units of damage.
C-Grade	The third level of quality. Although still usable, a C-grade exceeds a moderate amount of damage. C-grade parts require more than 2 units of damage.
X-Grade	This is an ungraded part. An X-graded part does not contain enough data for the information provider to grade the part.
NIQ	Negative information or quality. An abbreviation code recyclers use to have a part automatically downgraded to a C-grade part that otherwise would have met the mileage or damage units guidelines to be classified at a higher grade.
A-Grade Mechanical Parts	These parts have less than 60,000 total miles, or if over, must be less than 15,000 miles per model year of age.
B-Grade Mechanical Parts	These parts have equal to or greater than 60,000 miles and less than 200,000 total miles on them and have 15,000 miles or more per model year of age.
C-Grade Mechanical Parts	These parts have equal to or greater than 200,000 total miles on them regardless of age.

*A unit is defined as damage not exceeding the surface area of a standard-sized credit card.

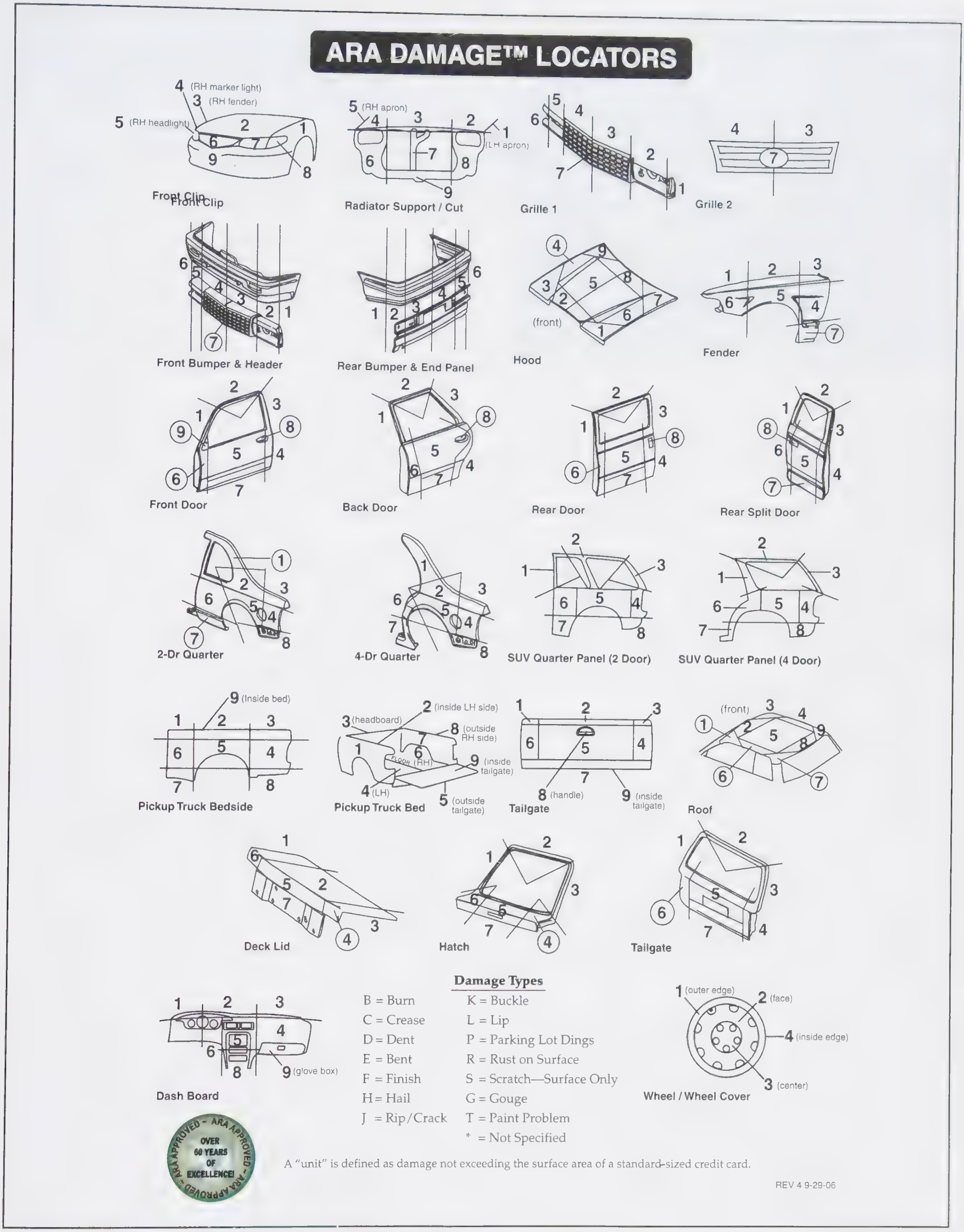
Damage Types

B = Burn
C = Crease
D = Dent
E = Bent
F = Finish
H = Hail
J = Rip/Crack
K = Buckle
L = Lip
P = Parking Lot Dings
R = Rust on Surface
S = Scratch-Surface Only
T = Paint Problem
G = Gouge
* = Not Specified

Figure 33-13. *This chart explains the codes used to indicate the condition of used parts. (ARA)*

Every vehicle has identification codes. These codes include the vehicle identification number, paint code, and trim code. The ***vehicle identification number (VIN)*** is found inside the driver's door or in the dash in front of the driver, viewable through the windshield, **Figure 33-15A**. The VIN includes information on the vehicle make, model, engine size, and production year, as well as the sequential production number. **Figure 33-15B** has a breakdown of the VIN. The VIN is needed on every estimate.

The ***paint code*** tells the technician what color is on the car. If the vehicle is two-tone, then there will be two paint codes. The paint code sticker, or plate, may be located on the driver's door, center pillar, under the hood, inside the trunk, or in the glove box depending on the type of vehicle. The ***trim code*** may be needed if trim parts such as molding need to be replaced. Some vehicle models are available in various levels of trim. The trim code will tell what level of trim is on the vehicle.


ARA DAMAGE™ LOCATORS
4 (RH marker light)
3 (RH fender)
5 (RH headlight)
Front Clip
5 (RH apron)
1 (LH apron)
Radiator Support / Cut
Grille 1
Grille 2
Front Bumper & Header
Rear Bumper & End Panel
(front)
Hood
Fender
Front Door
Back Door
Rear Door
Rear Split Door
2-Dr Quarter
4-Dr Quarter
SUV Quarter Panel (2 Door)
SUV Quarter Panel (4 Door)
9 (Inside bed)
Pickup Truck Bedside
3 (headboard)
2 (inside LH side)
8 (outside RH side)
FLOOR (RH)
9 (inside tailgate)
4 (LH)
5 (outside tailgate)
Pickup Truck Bed
8 (handle)
9 (inside tailgate)
Tailgate
(front)
Roof
Deck Lid
Hatch
Tailgate
9 (glove box)
Dash Board
1 (outer edge)
2 (face)
4 (inside edge)
3 (center)
Wheel / Wheel Cover
OVER 60 YEARS OF EXCELLENCE!
ARA APPROVED

Damage Types

B = Burn
C = Crease
D = Dent
E = Bent
F = Finish
H = Hail
J = Rip/Crack

K = Buckle
L = Lip
P = Parking Lot Dings
R = Rust on Surface
S = Scratch—Surface Only
G = Gouge
T = Paint Problem
* = Not Specified

A "unit" is defined as damage not exceeding the surface area of a standard-sized credit card.

REV 4 9-29-06

Figure 33-14. *This chart diagrams the various locations on body parts. (ARA)*

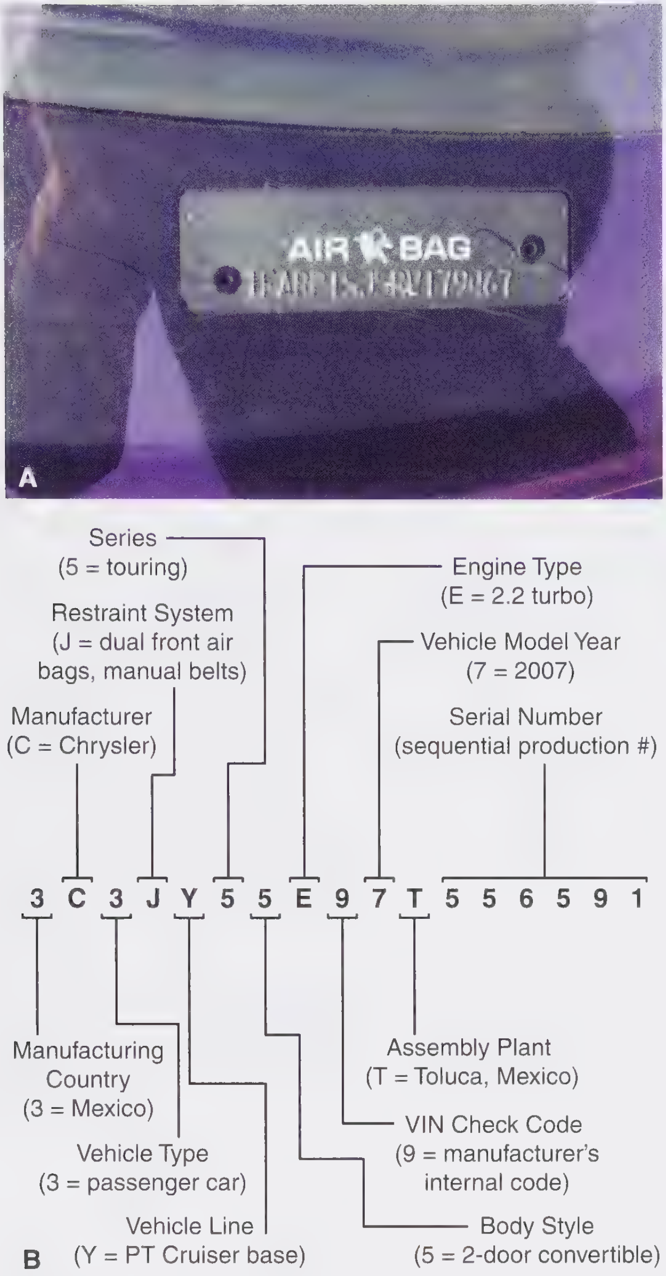

A
AIR BAG
Series
(5 = touring)
Restraint System
(J = dual front air bags, manual belts)
Manufacturer
(C = Chrysler)
Engine Type
(E = 2.2 turbo)
Vehicle Model Year
(7 = 2007)
Serial Number
(sequential production #)
3 C 3 J Y 5 5 E 9 7 T 5 5 6 5 9 1
Manufacturing Country
(3 = Mexico)
Vehicle Type
(3 = passenger car)
Vehicle Line
(Y = PT Cruiser base)
Assembly Plant
(T = Toluca, Mexico)
VIN Check Code
(9 = manufacturer's internal code)
Body Style
(5 = 2-door convertible)
B

Figure 33-15. *A—The VIN is visible through the windshield on the driver's side. B—The VIN contains codes for the body type, restraint system, engine series, and model year.*

There are a vast number of vehicle part names. Some parts have more than one name. For example, a center pillar is also called a B pillar.

The estimator must know the names of the vehicle parts, both body and mechanical. Major parts, which are made up of several smaller parts, are referred to as ***assemblies***. **Figure 33-16** lists some of the assemblies that are commonly damaged in a collision and the parts that make up each assembly.

Calculating Labor Charges

Understanding labor and how to charge for it is essential to the survival of the shop. Labor is the only source of income for technicians working on commission and a source of income for the shop. Everyone working in the shop should be concerned about labor. This section discusses what is included in the labor rate and explains labor allowances for flat rate labor, judgment labor, and additional labor.

There are two types of labor allowances: *flat rate* for panel replacement, and *judgment* for panel repair. Flat rate labor allowances are established by insurance and estimating companies. (Flat rate labor allowance is determined by first establishing the best way to perform a task, followed by a systematic examination of time/motion studies of technicians performing that task. These studies give insurance companies a pretty good idea of how long it takes a technician to accomplish the task.) See **Figure 33-17**. On the other hand, judgment labor allowances are set by the individual shop.

Flat Rate Labor Allowance

A ***flat rate labor allowance*** is the estimated amount of time, given in hours and tenths of an hour, required to perform a specified replacement or refinish task. A ***flat rate manual***, also called a collision estimating guide, lists flat rate labor allowances for replacing parts, moving and reinstalling parts, repairing panels, prepping for paint, and refinishing the vehicle. Flat rate manuals are arranged into the following books: GM, Ford, Chrysler, Asian, and European, older domestic, and older import. Each book covers several years of models. The books are updated at least four times per year because vehicle part prices change and new model vehicles are always being introduced.

The flat rate manual begins with a set of instructions. In the instructions, each vehicle is broken down into sections. The list of sections is arranged from the front to the rear of the vehicle. Every part that is commonly replaced due to collision damage is found in one of the sections. The sections list flat rate labor allowances for panel replacement and refinishing as well as part prices and part numbers. The last group of sections include refinish information, which specifies both included and not included refinishing tasks, special cautions about protecting computer modules, replacing seat belts, air bag/SRS inspection, replacement tables that list what air bag system components must be replaced or inspected, abbreviations of common automotive terms, plastic identification codes, and an estimating material reference list that gives the cost of various refinish and repair materials, paint code locations, and VIN decoding.

Assembly Components

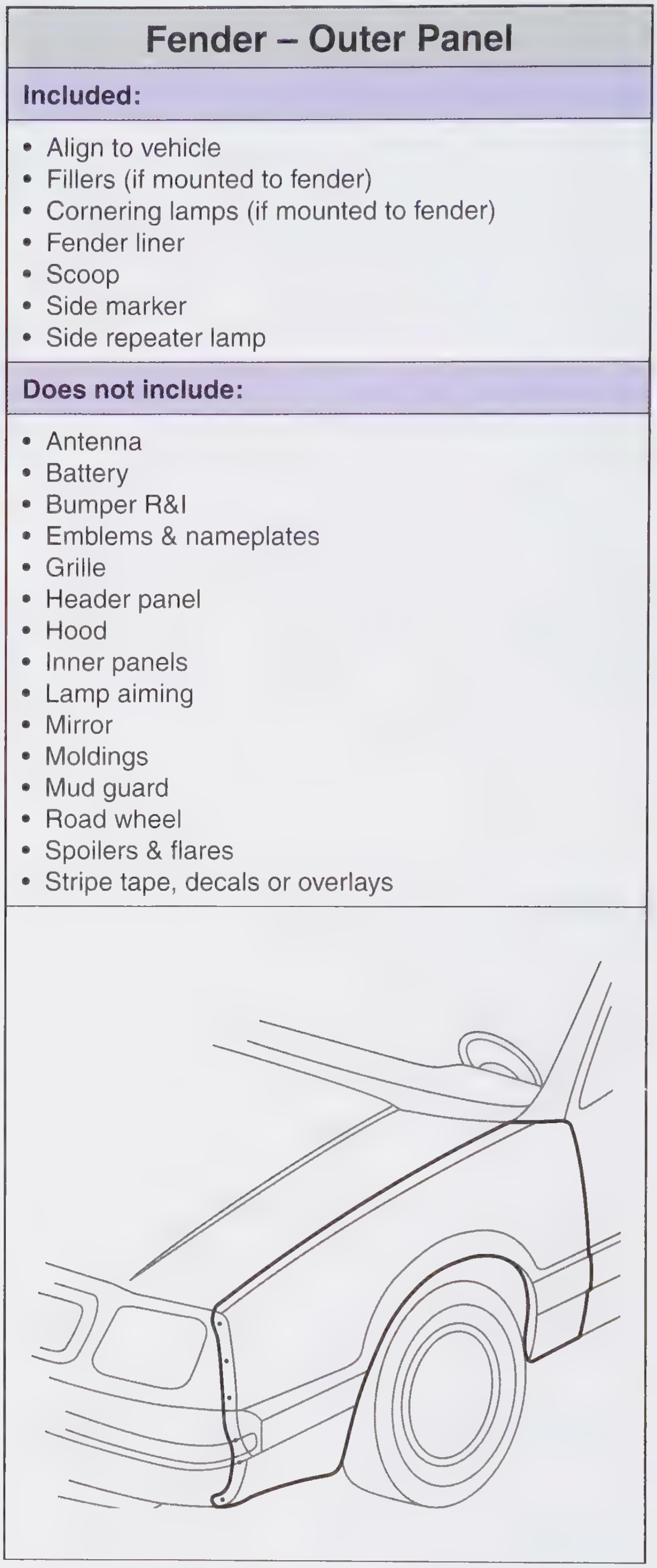
Assembly	Components	
Bumper: front or rear	Fascia or race bar Reinforcement Impact absorber or isolator	Moldings License plate bracket Turn signal lamp
Fender	Marker lamp Moldings	Fender liner
Hood	Hood latch Hood insulator	Hood striker Hood hinges
Header panel (not all vehicles have these)	Headlights Turn signals	Marker lamp Grille
Door	Door skin Striker Door latch Door handle	Moldings Door glass Key lock Door hinges
Roof	Rack	
Quarter panel	Marker lamp	Moldings
Deck lid	Key Lock Latch	Hinges Striker
Unibody structural parts	Radiator support Lower frame rail A pillar C pillar Rear body panel	Upper frame rail Rocker panel B pillar Rear frame rail
Full frame structural parts	Side rail	Cross members
Pickup truck parts	Cab Bed	Cab corner Tail gate
Air bag	Module Clock spring	Sensor
A/C system	Condenser A/C line	Drier
Cooling system	Radiator Fan	Radiator shroud Fan clutch
MacPherson strut suspension	Strut Ball joint Control arm	Spring Spindle
Long arm/short arm suspension	Upper control arm Ball joint Spring	Lower control arm Shock absorber
Rear suspension	Rear axle housing Rear axle Spring	Shock absorber Strut
Rack and pinion steering	Rack Tie rod	Steering knuckle Tie rod end
Conventional steering	Gear box Pitman arm Center link Steering knuckle	Idler arm Tie rod Tie rod end

Figure 33-16. *Vehicle parts referred to as assemblies include the components listed here.*

Figure 33-17. *Flat rate labor allowance, the estimated amount of time required to perform a specific task, is determined by establishing the best way to perform the task, followed by an examination of time/motion studies of technicians performing that task. These studies give insurance companies an excellent idea of how long it takes to complete a task such as the one depicted above.*

A section from a flat rate manual is shown in **Figure 33-18**. The section lists what is included and not included in the labor allowance for front fender R&R (remove and replace). For example, if the labor allowance to R&R a fender is 2.2 hours, the allotted time includes removing the bolts and taking the fender off the car, removing the side marker lamp and fender liner off the damaged fender and installing it on the new fender, installing the new fender, aligning it to fit, and tightening the bolts. However, the 2.2 hour labor allowance does not cover: removing and installing the front bumper, antenna, wheel, or battery. If any of these operations are required, an additional labor allowance must be added. A thorough understanding of what is included and what is not included is essential to writing a good estimate. **Figure 33-19** shows examples of items not included in the flat rate labor allowance.

Factors are numbers used to multiply flat rate labor allowances when calculating a labor allowance for an operation such as blending or clearcoating. For example, to calculate the labor allowance for blending a panel, the refinish labor allowance is multiplied by 0.5.



Fender – Outer Panel

Included:

- Align to vehicle
- Fillers (if mounted to fender)
- Cornering lamps (if mounted to fender)
- Fender liner
- Scoop
- Side marker
- Side repeater lamp

Does not include:

- Antenna
- Battery
- Bumper R&I
- Emblems & nameplates
- Grille
- Header panel
- Hood
- Inner panels
- Lamp aiming
- Mirror
- Moldings
- Mud guard
- Road wheel
- Spoilers & flares
- Stripe tape, decals or overlays

Figure 33-18. *This page from a flat rate labor manual lists what is included and not included in the labor allowance for fender replacement.*

Not Included in Panel Replacement Labor Allowances

1. Drill holes in new parts
2. Adhesive removal
3. Recode lock cylinder
4. Transfer VIN label on door
5. R&I emblems/nameplates/moldings
6. Retape emblems/nameplates/moldings
7. R&I nonstandard equipment
8. Aim lamps
9. Install sound deadening
10. Clean up broken glass
11. Pull damaged panels for access
12. Cut off rusted bolts or nuts
13. Drill out broken bolts
14. Protect adjacent panels from weld damage
15. D&R battery when MIG welding
16. R&I accessory items
17. R&I spoiler/flares
18. Adjust/bleed brakes
19. R&I cargo from pickup truck bed
20. R&I trailer hitch
21. R&I pickup truck topper
22. D&R computer when welding
23. R&I removable bed liner
24. Apply weldthrough primer
25. Fit aftermarket parts
26. R&I wiring
27. R&I fuel from gas tank and store
28. D&R battery on hybrid vehicles
29. Transfer emissions sticker on hood
30. Clean up used parts
31. Remove special wheel lock
32. Install rustproofing on new parts
33. Disassemble used part
34. Wheel alignment
35. Clean vehicle before repairs
36. Measure before repairs
37. Fabricate sleeves
38. Inspect restraint system
39. Test fit parts
40. Remove and replace undercoating

Figure 33-19. *This chart lists what is not included in panel replacement. If a labor operation is not included, a separate labor allowance should be made.*

A door will be blended and the refinish labor allowance to refinish the door is 2.4 hours. To calculate the blend labor allowance, multiply 2.4 hours (the refinish labor allowance) by 0.5 (blend factor). The blend labor allowance is 1.2 hours. The factor of 0.5 indicates that it takes half as much time to blend a panel as it does to refinish it. Factors for various operations, including buffing and clearcoating, are summarized in **Figure 33-20**.

Overlap is deducted from flat rate labor allowances when replacing one component which makes it easier to replace another component, or when replacing one component is part of another operation. Overlap is deducted for body, paint, and mechanical labor. Overlaps are common in refinishing when multiple panels, especially adjacent panels, are painted.

The following examples are from a flat rate manual that lists the replacement of new, OEM parts.

Body Labor Allowance

Figure 33-21 shows a damaged unibody vehicle. In this example, the vehicle needs a bumper cover and an energy absorber (in addition to the right headlight and fender). The labor allowance to O/H (overhaul) the bumper assembly is 1.8 hours. Energy absorber replacement is included in the labor allowance for a front bumper overhaul, so additional labor is not needed. The vehicle has fog lamps. The right fog lamp is damaged (on the back side, not visible in the photo). According to the flat rate labor guide, 0.3 hours should be added to O/H if the vehicle has fog lamps. A lower grille is also needed. A lower grille replacement is included in the overhaul, so no additional labor allowance is added to the total.

Mechanical Allowance

Mechanical labor is indicated by an “m” or “me” in the flat rate manual. The vehicle shown in **Figure 33-22** has a damaged A/C condenser. The flat rate labor allowance for condenser replacement is 1.0 hour. (Many shops charge a higher labor rate for mechanical and frame repairs than for body and paint labor.) The R&R of the condenser does not include time to recover the refrigerant or to evacuate and recharge the A/C system. This additional labor must be added to the estimate.

Refinish Labor Allowance

The vehicle depicted in **Figure 33-23** has three damaged panels that must be painted. The paint labor allowance is listed for each panel in the flat rate manual. A refinish labor allowance must also be given for clearcoating panels. The formula for calculating clearcoat allowance is 0.4 hour per refinish hour for the first major panel and 0.2 hour per refinish hour for each additional panel.

Factors
Clearcoat/two stage finish—0.4 per refinish hour for the first major panel or soft bumper/fascia cover including jambs, interior or underside; included operations mix material, clean and tack surface, apply material, clean equipment.
Clearcoat/two stage finish—additional panels after the first panel, deduct overlap from refinish time 0.2 per refinish hour including jambs, interior and underside; included operations: clean and tack surface, apply material.
Three stage refinish—0.7 per refinish hour for the first major panel or soft bumper/fascia cover including jambs, interior or underside; included operations: mix pearl /mica toner, apply toner to test panel, mix clear, clean and tack surface, apply clear to test panel, repeat application to surface being refinished, clean equipment.
Three stage refinish—additional panels after the first panel, deduct overlap from refinish time 0.4 per refinish hour including jambs, interior and underside; included operations: apply pearl/mica toner, clean and tack surface, apply clear.
Two-tone refinish—first major panel 0.5 per refinish hour; included operations: mask panel, scuff panel, mix material, apply material, clean equipment.
Two-tone refinish—additional panels, deduct overlap add 0.3 per refinish hour; included operations: mask panel, scuff panel, apply material.
Blend panels single stage or basecoat/clearcoat (applying basecoat to only a part of a panel and clearcoat on the entire panel)—0.5 per refinish hour, no overlap deduction; included operations: detergent/solvent wash, scuff panel, mask adjacent panels (to 36 inches), apply adhesion promoter, spray basecoat, tack, spray clearcoat. Not included are any repairs to the surface of the blended panels or removal of obstructions.
Blend panels three stage paint (applying basecoat and midcoat to only part of a panel and clearcoat on the entire panel)—0.7 per refinish hour; included operations: detergent/solvent wash, scuff panel, mask adjacent panels (to 36 inches), apply adhesion promoter, spray base coat, tack, spray midcoat, tack, spray clearcoat. Not included are any repairs to the surface of the blended panels or removal of obstructions.
Extend blend (applying clearcoat only to the entire panel)—0.5 hour per refinish hour; included operations: detergent/solvent wash, scuff panel, mask adjacent panels (to 36 inches), apply adhesion promoter, tack, spray clearcoat. Not included are any repairs to the surface of the blended panels or removal of obstructions.
Color sand and buff—0.3 per refinish hour no overlap is deducted each panel refinished; includes color sanding clearcoat, buffing to gloss, application of glaze.

Figure 33-20. *These factors are multiplied by the refinish labor allowance to calculate clearcoat, two-tone, tri-coat, blend, and buffing labor allowance.*

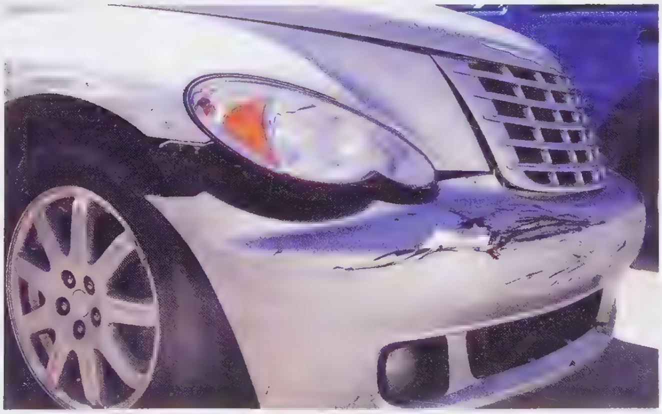


Figure 33-21. *This unibody vehicle has damage to the front bumper assembly, fender, headlamp, and A/C condenser.*

Figure 33-22. *A flat rate labor manual will designate mechanical labor with an "m" or "me". Mechanical labor, such as the replacement of an air conditioner condenser, is charged at a higher labor rate.*

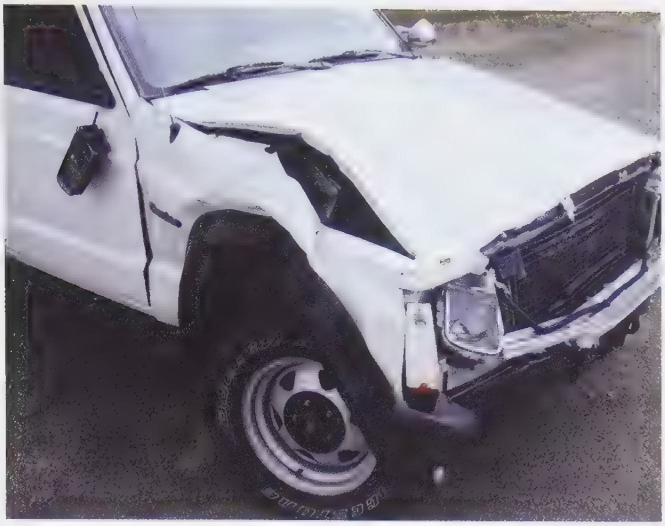


Figure 33-23. *Each of these damaged panels has a labor allowance. It is found in the collision estimating guide.*

For example, the allowances for fender painting and edging add up to 2.6 hours. The clearcoat time for the fender is 2.6 hours × 0.4 = 1.0 clearcoat hour. The front bumper is considered a separate operation because bumper covers are repainted off the vehicle. The clearcoat time for the bumper is 2.6 hours × 0.4 = 1.0 hour clearcoat. Time can also be added to color sand and buff. The allowance for sanding and buffing is 0.3 hour per refinish hour. Time may also be needed to mask interior jams. Clearcoat time is not figured on blend panels.

The entire panel may not need to be painted if the damage covers less than half the panel. To calculate partial painting of a panel, divide the refinish time for the part by 2. Figure in the full clearcoat time for the panel.

Refinish labor allowances include the time needed to mask adjacent panels up to 36" away from the refinish panel. All masking labor allowances are added to refinish labor allowances so they trigger a paint material cost that includes the cost of the masking material. Not included in refinish labor allowance is the internal masking of doorjambs, fender flanges, internal deck lid/rear hatch, or hood openings. When calculating refinish labor allowances, add 0.3 hour to mask a hood opening, 0.2 hour for each fender flange, 0.3 hour for each doorjamb, 0.2 hour for each quarter panel flange, and 0.3 hour for each deck lid/rear hatch opening. Most shops cover the vehicle with masking plastic twice, once for undercoat application and again for topcoat application. Add 0.2 hour to the paint labor for the two applications of masking plastic. If liquid mask is applied to the frame and wheel wells, add 0.6 hour for loading, applying, spray gun cleaning, and mask removal.

Obstructions interfere with efficient panel painting. Ideally, a panel should have no obstructions on it during painting. Obstructions can be defined as anything that covers or touches a surface to be painted, such as moldings, handles, nameplates, bumper covers, and even the windshield and back glass. Obstructions have been removed from the vehicle prepared for repainting shown in **Figure 33-24**. The time needed to R&I obstructions is listed in collision estimating guides. There is no standard for what should be removed. Each shop must identify the parts that should be removed and the parts that should be left on.

Flat rate manuals are also available for used assemblies. The used-assembly flat rate manual lists labor allowances for the replacement of used parts. Part prices are not listed, but labor allowances for replacement and refinishing are included. The labor flat rate allowances for used parts are different from those for new parts.

The flat rate manual is only a guide. Labor allowances are not law; they are a recommendation. Body shop estimators are free to write the labor estimate as they see fit. In some cases, the flat rate manual may not reflect the true time required to complete a panel replacement. If that is the case, the estimator must decide on the correct amount of time and adjust the labor allowance accordingly.

Judgment Labor Allowance

Flat rate manuals list the amount of time required to *replace* panels, but they do not list time required to repair damage. Repair labor is also called judgment labor.

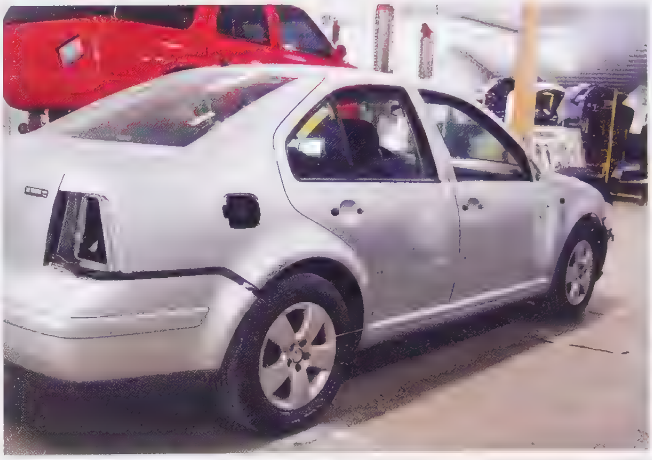


Figure 33-24. *The right side of this vehicle will be repainted. Notice that the bumper covers have been loosened and the door moldings and handles have been removed.*

An estimator examines the damage and calculates how many hours of labor are required to repair the damage. The time required to repair the damage is called a ***judgment labor allowance***. This section explains how to use formulas to calculate judgment labor allowances for several different types of damage.

An experienced estimator can often inspect damage and quickly decide on a fair yet profitable judgment labor allowance. A beginning estimator may want to use a formula to calculate judgment labor allowances.

There is no industry standard for the formulas used to calculate judgment labor allowances. The formulas used in the examples that follow are subjective. Each shop should determine formulas for judgment labor allowances based on the equipment available, shop-specific repair procedures, and the skill of technicians.

Steel or Aluminum Panel Repair Allowance

The typical formula for calculating the repair judgment labor allowance for steel or aluminum panel is as follows:

Panel repair judgment labor allowance =
access time + straightening time + fill time

Access time is the time required to remove obstructions. Tasks that should be considered in determining access time are shown in **Figure 33-25**. The time required to perform these tasks can be found in a flat rate manual.

Before calculating straightening time and fill time, you must first determine the units of damage that must be repaired. One unit of damage is equal to the surface area of a credit card (3 3/8" × 2 1/8"). See **Figure 33-26**. To determine the total units of damage, take a credit card and use it to measure the repair area.

To calculate straightening time, the total units of damage are multiplied by one of two factors. If the damage area has no body line, multiply the units of damage by 0.5 to arrive at the straightening hours. If the damage area has a body line, multiply the units of damage by 1.0.

If shrinking or stretching is required, it should be added to the straightening time calculated in the previous step. If heat shrinking is required, add 0.5 hour to the straightening time. If stretching is required, add 1.0 hour to the straightening time. For hail damage, add 0.5 hour per hail dent to the straightening time.

Fill time includes mixing, applying, and block sanding filler. To determine fill time per unit of damage, refer to **Figure 33-27**.

Access Time Tasks

Fender Repair

- R&I headlamp
- R&I front bumper cover
- R&I moldings
- R&I trim
- R&I fender liner
- R&I antenna

Hood Repair

- R&I insulator
- R&I trim
- R&I windshield washer nozzles

Door Repair

- R&I trim panel
- R&I moldings
- R&I handle
- R&I lock cylinder

Roof Repair

- R&I headliner
- R&I trim
- R&I windshield and moldings
- R&I back glass and moldings

Quarter Panel Repair

- R&I trunk liner
- R&I taillight
- R&I rear bumper cover
- R&I moldings
- R&I marker lamp

Deck Lid Repair

- R&I lock cylinder
- R&I moldings

Rear Hatch Repair

- R&I lock cylinder
- R&I moldings
- R&I back glass and moldings
- any of the above parts may have aftermarket accessories that need to be removed or replaced

Figure 33-25. *Access time is the time necessary to remove obstructions. This chart lists the tasks that are part of a repair.*

Surface Prep Allowance

Refinish labor allowances for panels are listed in flat rate manuals. Labor allowances for surface prep are not listed and must be calculated by the estimator.

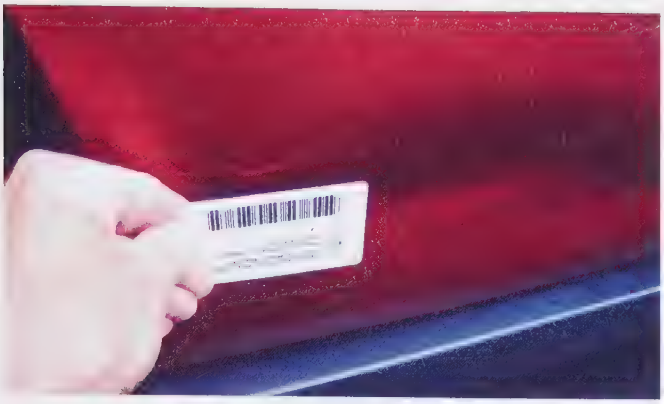


Figure 33-26. *A credit card is used to measure a standard area of damage. The surface area of a credit card is considered to be one unit of damage.*

Surface prep labor allowances include time to clean the repair area with soap and water; wipe down with wax and grease remover; featheredge the damage area with 80-, 180-, and 320-grit sandpaper; mask the vehicle for undercoat application; mix and apply primer; clean the spray gun; mix and apply surfacer; clean the spray gun; and block sand the cured surfacer. A chart listing surface prep times by unit of damage is shown in **Figure 33-28**. Note that surface cure time is not included in the formula. Cure time can be shortened by the application of heat or air current, but cure time is not labor time because the vehicle is not being worked on by the technician. If the body shop follows a different procedure, such as two applications of surfacer rather than one, the shop should decide on what times will be allowed.

Fill Time Labor Allowance	
Units of Damage	**Fill Time**
1	0.5
1.5	0.7
2	0.9
2.5	1.1
3	1.3
3.5	1.5
4	1.7
4.5	1.9
5	2.1
5.5	2.3
6	2.5
6.5	2.7
7	2.9
7.5	3.1
8	3.3
8.5	3.5
9	3.7
9.5	3.9
10	4.1

Figure 33-27. *The fill time labor allowance is calculated by the units of damage.*

Surface Prep Labor Allowance	
Units of Damage	**Surface Prep Labor Allowance**
1	1.0
1.5	1.1
2	1.2
2.5	1.3
3	1.4
3.5	1.5
4	1.6
4.5	1.7
5	1.8
5.5	1.9
6	2.0
6.5	2.1
7	2.2
7.5	2.3
8	2.4
8.5	2.5
9	2.6
9.5	2.7
10	2.8

Figure 33-28. *The surface prep labor allowance is calculated by the units of damage.*

If a draw pin welder will be used in the repair, or if the panel was welded, add 0.5 hour for the application of epoxy primer to the back of the panel. If a panel has cosmetic damage, such as a minor scrape or a key scratch, use the following formula to calculate surface prep labor allowance:

Repair allowance =
access time + 1.5 hour per 6" of scratch or scrape

If the scrape is taller than 1", multiply by 2.0 hours rather than 1.5 hours per 6" of scrape. (Access time is the time needed to remove parts, such as the bumper cover, and time required to remove obstructions.)

Surface prep labor allowance is added to the refinish time, so a charge can be made for undercoat materials.

Plastic Repair Allowance

Damage to plastic parts usually consists of scratches, dents, or tears. Non-cosmetic scratches are repaired by cleaning, featheredging, filling, sanding, surfacing, and blocking. The formula to calculate the labor allowance:

Plastic panel scratch labor allowance =
access time + 1.5 hours per each 6" of scratch for clean, featheredge, fill, and sand time

Add to this 1.5 hours surface prep time for scratches up to 6" in length. If the scratch is longer than 6", add 0.5 hour for each additional 6".

Dents can often be removed by heat and shaping. The formula used to calculate dent removal by heat is:

Plastic panel dent removal labor allowance =
access time + 0.5 hour per each unit of damage

Add to this the surface prep time. To calculate the repair of a tear:

Plastic tear repair labor allowance =
access time + 0.2 hour per inch of tear

This labor allowance includes time to clean the repair area, featheredge the front and back of the tear, cut out backing material, mix adhesive, apply adhesive and backing material to the back of the tear, cure, apply filler to front of the tear, and sand the filler. Add to this 1.0 hour surface prep time for up to 6" of scratch. If the scratch is longer than 6", add 0.5 hour for each additional 6".

Figure 33-29 shows a damaged bumper cover. The tear is 7" long. The repair allowance is figured by adding:

> Tear allowance (7" × 0.2 hour/inch = 1.4 hours) and access time (0.8 hour to R&I the bumper cover). Add to this surface prep time (1.0 hour for the first 6" plus 0.5 hour for the next 1" = 1.5 hours) to arrive at 3.7 hours total judgment labor allowance.

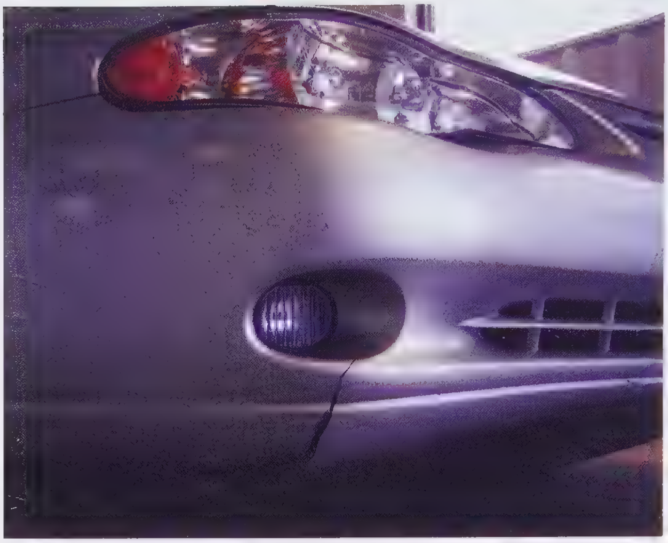


Figure 33-29. *This bumper cover is repairable. Measure the length of the tear to determine the judgment labor allowance. The cover will need to be removed for access to the back side.*

Full Frame Repair Allowance

Full frame repair judgment labor allowance is calculated by the following formula:

Full frame repair judgment labor allowance =
access time + 1.5 hours measuring time + 1.0 hour tiedown time + correction time

The correction times of various types of damage are shown in **Figure 33-30**. Buckles in box frames may require that a window be cut into the frame to allow the technician access to the back side of a buckle. Access time includes removing or moving, and reinstalling, obstructions such as pickup truck bed or cab, running boards, gas tank, gas lines, brake lines, and rear bumper. Pickup trucks and SUVs may have an accessory trailer hitch that must be removed and reinstalled.

Unibody Repair Allowance

Calculation of unibody repair allowance is slightly different than the calculation for a full frame repair. Here is the formula for calculating unibody repair judgment allowance:

Unibody repair judgment time =
access time + 2.0 hours measuring time + 0.7 tiedown time + correction time

The correction times for various types of unibody damage are shown in **Figure 33-31**. Access time includes time needed to remove obstructions such as gas lines, brake lines, and electrical wires. Details such as rewelding torn spot welds and tears, and cutting and welding access windows are usually not going to be written on an estimate. These are tasks that may need to be performed during the repair.

Full Frame Repair Correction Allowances

Damage	**Allowance**
Diamond	6.0 hours
Twist	6.0 hours
Sag or kickup (per rail)	3.0 hours
Sidesway (per rail)	3.0 hours
Mash (per rail)	4.0 hours
Individual frame rail twist	3.0 hours
Cross member buckle	3.0 hours
Cracked frame rail weld	1.0 hour per 4 inches
Splice frame rail	6.0 hours
Cut access window in rail and reweld	2.0 hours

All correction allowances include time to plan the pull.

Figure 33-30. *Judgment labor allowance for full frame repair is calculated by consulting this chart.*

Unibody Repair Correction Allowances

Damage	**Allowance**
Twist	5.0 hours
Sag or kickup (per rail)	2.5 hours
Mash (per rail)	3.5 hours
Sidesway (per rail)	2.5 hours
Sidesway of center pillar	3.0 hours
Sidesway of cowl	4.0 hours
Reweld torn spot welds during repair	0.5 hour per spot weld
Reweld tears during repair	0.5 hour per inch
Cut access window in rail and reweld	4.0 hours

All correction allowances include time to plan the pull.

Figure 33-31. *Judgment labor allowance for unibody repair is calculated by consulting this chart.*

R&I or R&R Allowance

Judgment labor allowances must be figured in for part replacement when there is no allowance listed in the flat rate manual, or if a flat rate manual is not available for the vehicle. Flat rate manuals do not list labor allowances for aftermarket accessories. Allowances for R&R (remove and replace) or R&I (remove and install) of running boards, bed liners, toppers, visors, mud flaps, stripe tape, and any other aftermarket accessory must be calculated by the estimator. To calculate judgment labor allowance for an aftermarket accessory, look at the part on the vehicle and visualize what steps the technician would need to take to remove it. Try to determine how it is fastened. If it is bolted on, are the bolts rusty? Running board supports are usually rusted in place, and removal of the bolts may require heat. Installation may require the use of new bolts. Figure at least 1 hour labor allowance for anything but the easiest-to-remove aftermarket accessories. Use the same reasoning when deciding how much time is needed to install the part and calculate accordingly.

Accessory parts may be damaged during removal. Decide ahead of time who will bear the cost of replacing the damaged part.

Additional Labor Allowance

Labor not listed in a flat rate manual and not part of judgment time is called additional labor. For example, all vehicles must be cleaned before delivery. The time required to clean the vehicle after repair should be included in the estimate. Add 1–2 hours of body labor to the estimate for vehicle cleaning. If the vehicle windows and doors are closed during the repair process, figure 1.0 hour to clean the vehicle. If a window or door must be kept open during the repair process, add 2.0 hours. The extra time is added to clean the dust inside the vehicle.

Other examples of additional labor include cleaning up broken glass; modifying aftermarket parts to make them fit; repairing damage or rust on used parts; opening doors, hoods, or deck lids that have been smashed closed; removing undercoating or rustproofing; removing or covering parts before welding; measuring damage; and planning the repair.

If the seat belts were in use during the crash, the belt webbing, buckle, and retractor should be checked for strain or damage. Any weakened component in the restraint system must be replaced. Add 0.5 hour to check the seat belts. If an air bag was deployed during the collision, add labor time to inspect the system components that will not be replaced.

A vehicle must be grounded before MIG welding. This requires a bare metal surface for work clamp attachment. For example, when a radiator support is replaced, the adjacent apron may need to be sanded to bare metal to attach the work clamp. MIG welding also requires the D&R (disconnect and reconnect) of the negative battery cable and any nearby computer modules. Heat generated by welding can burn adjacent panels, so provisions must be made to protect surrounding surfaces.

How many hours should be added to the estimate for these activities? If there is no set amount listed in the manual, take these additional tasks into consideration when preparing the estimate.

Other additional labor includes tinting a refinish color to match the vehicle color; laying out stripes or designs for custom paint; removing and installing a bed liner, topper, tool boxes, and hitches on pickup trucks. A pickup truck bed may also contain cargo or traction weights that must be removed and replaced during the repair process.

Prices

A body shop has two sources of income: selling technician labor and selling parts. Pricing in a body shop is generally set up to make a 25% profit on all parts and materials sold to the customer. Prices for OEM parts may be obtained from a current collision estimating guide, from a current computer estimating system, or by calling the dealer. Part prices fluctuate, down as well as up. Therefore, a parts pricing source should not be more than one month old. Call the dealer if there is any doubt about the price of an OEM part. Aftermarket and used part prices are determined by calling the supplier or by looking at the supplier's website.

Parts Prices

The source of parts has the biggest influence on how much they will cost. Getting parts at the right price is important to a body shop's profitability. It is the estimators' job to accurately determine the price of parts used for a repair. OEM parts prices are found in a collision estimating guide or in a computerized estimating program. Be aware that prices in an out-of-date collision estimating guide may be wrong. It is important to always use the latest pricing sources, as prices for parts and materials may change several times per year.

Collision estimating guides and computerized estimating programs list part numbers and prices, as well as labor times. To obtain the right price, the correct part number must be known. This is not always obvious, as there are many choices for parts on some vehicles. Actually seeing a diagram or drawing of the part in the collision estimating guide or on a computer screen will help. Part numbers may be listed with a hyphen before the final number, such as 123356-7. This means that the part number for the right side of the vehicle is 123356, while the part number for the same part on the left side is 123357. Once the part number is known, the OEM dealer can obtain the price. The retail price is listed in the guide. The body shop will pay wholesale price. The wholesale price is usually a 25% discount off the retail price. Buying the part at wholesale and selling it at retail nets a body shop the required 25% profit.

Information on aftermarket parts is generally found in an aftermarket catalog or website. The catalog lists the part name and part number, as well as retail and wholesale prices. Prices may also be obtained by calling the aftermarket dealer.

Used part prices are obtained by calling a salvage yard or visiting the salvage yard's website. If the assembly is available, the yard will give the estimator the price. The price the customer will be charged, the retail price, can be calculated by taking the body shop's price and multiplying it by the markup factor. To reflect the 25% discount offered by OEM wholesale prices, multiply the wholesale price charged by the salvage yard by the 1.33 markup factor. The standard in the automotive industry is a 25% discount off the retail price. For example, a part that costs the shop $100 will cost the customer $133.

Material Prices

Material prices are figured separately from part prices. There are three types of materials: paint, body, and mechanical. The pricing of all three types of materials is related to the number of labor hours plus any materials not included in a standard repair. A body shop should price materials to make a 25% profit.

Refinish Material Prices

Paint material price is related to how much surface prep and refinishing labor is performed. To simplify the calculation, the number of surface prep and refinishing labor hours are added together; then the sum is multiplied by a factor to determine the charge for paint material. The factor depends on the price of paint. A reference for material prices is found in flat rate manuals. The refinish material price includes the items listed in **Figure 33-32**. Materials not listed should be noted on the estimate and charged to the customer. Items that are typically not included in the paint material price include flex additive for flexible bumper covers, multi-hue basecoats, aftermarket stripe tape, and aftermarket paint protector.

Refinish Material Included in the Factor

- Masking plastic for undercoats and topcoats
- Masking tape for undercoats and topcoats
- Masking paper for undercoats and topcoats
- Masking foam for undercoats and topcoats
- Liquid mask for undercoats and topcoats
- Spray booth coating
- Car wash soap
- Wax and grease remover
- Paper towels or wipers
- Sandpaper disks
- Sandpaper sheets
- Scuff pads
- Guide coat
- Primer/reducer
- Surfacer/hardener
- Sealer/reducer
- Adhesion promoter
- Basecoat/reducer
- Clearcoat/hardener
- Tack rags
- Gun wash thinner
- Buffing/rubbing compound
- Buffing pads
- Rust proofing
- Razor blades
- Glass cleaner
- Water

Figure 33-32. *These materials are included in the factor used to multiply refinish and surface prep labor allowances when calculating paint material cost.*

Body Material Prices

Body material price for panel repair is calculated by multiplying the units of damage by a factor. Body materials may also be used in panel replacement. For example, if a replacement quarter panel is welded, the weld area must be filled after grinding. In quarter panel replacement, allot 2.0 units of damage to fill the weld joint. For door skin replacement, allocate 1.0 unit of damage if the window channel is spliced. Allot 3.0 units of damage to fill the four corners of the roof during roof replacement. The factor is subject to change depending on the cost of materials. Body materials included in the cost of panel repair are listed in **Figure 33-33**. Single-use plastic fasteners or clips, plastic repair material, vibration damping pads, windshield or glass urethane, glass primer, door skin adhesive, and panel adhesive are not included in the body material price and should be charged separately.

Body Materials Included in the Factor

- Clean wipers
- Wax and grease remover
- Grinding disks
- Cutoff wheels
- Body filler
- Draw pins
- MIG welding gas
- MIG welding wire
- Sandpaper disks
- Sandpaper sheets
- Body filler/hardener
- Final filler/hardener
- Guide coat
- Weld through primer
- Seam sealer
- Body side molding tape

Figure 33-33. *This guide lists the various body and paint repair materials included when factoring an estimate.*

Mechanical Material Prices

When an oil pan, transmission, or rear axle is repaired, the fluids and oils must be added to the estimate. If a radiator is replaced, add the correct amount of antifreeze to the estimate. If the condenser or A/C line is replaced, add the cost of A/C refrigerant, O-rings, and possibly, A/C oil.

Labor Rate

The labor rate is the number of dollars charged per hour of labor. It is set by the shop, but is dictated by the prevailing area wage. A ***prevailing area wage*** is defined as the hourly rate paid for work of a similar character in the locality in which the work is performed. Insurance companies pay the prevailing area wage. To prevent price fixing, shops in an area cannot agree to set the labor rate at a certain dollar amount. ***Price fixing*** is a conspiracy between body shops to sell their services at a fixed price. The intent of price fixing is to push the price of the service as high as possible and this practice is illegal.

If a body shop charges more than the prevailing area wage the insurance company may require the customer to pay the difference between the two rates. Body shops have different labor rates for different tasks.

Body labor includes panel repair and replacement of bolted, bonded, and welded panels. Paint labor includes cleaning, masking, mixing, spraying, and buffing. Usually, body labor rates and paint labor rates are the same. Frame repair labor, which requires more skill and equipment than body labor, is charged at a higher rate than body/paint labor. The mechanical labor rate is also higher than the body labor rate. The labor rate is usually the same for frame and mechanical labor.

Additional Charges

Depending on the situation, some estimates may list ***additional charges***. These charges are for fees or services performed by the shop or a sublet company. Additional charges include disposal fees and sales tax. Not all damage may be located when writing an estimate. Hidden damage discovered during tear down or repair is also listed as an additional charge.

Disposal Fees

Body shops are required by law to properly collect, store, and dispose of hazardous waste and keep a record of compliance. Body shops pay for contracts with hazardous waste disposal companies to remove, transport, and dispose of hazardous waste. To defray these costs, a flat fee is added to every estimate for hazardous waste disposal. When a tire is replaced, the junk tire must be properly disposed of. The customer is charged a fee to cover the cost of junk tire pickup and disposal.

Sublet Labor

Nondriveable vehicles must be towed to a body shop for repair. Some body shops have their own towing service. Other shops must rely on an independent towing company. Most shops will add 25% to the independent towing company's bill and charge it to the customer. Many shops do not perform glass removal, A/C service, or alignments. These operations would be sublet to an independent company. It is common practice to mark up sublet bills by 25% when determining the customer's total cost.

Sales tax

The amount of sales tax charged on parts and materials, and possibly labor, is determined by state and local laws. If tax is charged on parts and materials, add these two totals together and then multiply the sum by the sales tax rate. For example, if parts and materials add up to $100 and the tax rate is 7.5%, multiply $100 by 0.075 to arrive at the total amount of sales tax that should be added to the total. In this case, $7.50 in sales tax would be added to the total.

Add-ons

Additional damage may be discovered as the vehicle is disassembled during repair. Any additional parts or labor not on the original estimate is considered an add-on. Add-ons are sometimes called supplements. In situations other than direct repair, the body shop contacts the insurance company about the additional damage with a list of required parts and labor. The body shop can e-mail a photo of the damage to the insurance company, or the insurance company can send an estimator/adjuster to the shop to approve the request.

NOTE

Some shops have special add-on forms for the technician to fill out, while others use a computer to record the required documentation.

Add-ons slow down the repair process because vehicles are not usually brought into the shop for repair until all the parts are received by the body shop. The parts in the add-on may not be delivered to the shop for several days. In the meantime, the vehicle will sit in the shop with no parts to install.

Writing Estimates

The estimate is the first and perhaps the most important aspect of the collision repair business. No one can be paid if the repair job goes to another shop. Estimates may be handwritten or computer-generated.

Handwritten Estimate

The estimator must understand instructions in a flat rate labor manual for labor allowance, part prices, part numbers, and be able to calculate overlap and paint times to produce a good handwritten estimate. The first step is to select the appropriate flat rate manual, one that is based on the make and year of the vehicle being repaired. Locate the model of the vehicle in the manual. In the manual, parts for each model are arranged from the front of the vehicle to the rear of the vehicle. Follow this front-to-back format when writing the estimate.

The most common mistake made when writing an estimate is forgetting to include a part or a repair operation. Look at each part in the damaged area and determine if the part is damaged or missing. By working through each damaged area and looking at each part, the estimator can keep track of what parts are needed. **Figure 33-34** shows a method of keeping track of parts when writing a long estimate. In this example, notice how each part is given a number as it is written on the estimate. The number corresponds to the line number on the estimate. The estimator can tell at a glance if a part has been covered and where it is on the estimate.

A handwritten estimate form is shown in **Figure 33-35**. The header section, marked in yellow, has lines for the customer's name, address, phone number, and insurance company. The header also has spaces for vehicle information: make, model, year, VIN, and license plate number. The next sections are arranged in columns from left to right, with lines from top to bottom. In the operation/part column, colored green, the estimator writes what will be done to the vehicle on each line. The abbreviations R&I or R&R are used here if panels will be removed; the word "repaired" is entered if panels will be repaired.

If a part will be replaced the part number is listed in the part number column, which is colored brown. The price of the part is written in the price column, which is colored blue. Body labor and paint labor, measured in hours and tenths of an hour, are entered into the purple body labor column. The disclaimer section, colored red, explains that the estimate does not cover damage found after work is started. The authorization is signed by the customer to allow the body shop to make the repairs based on the estimate.

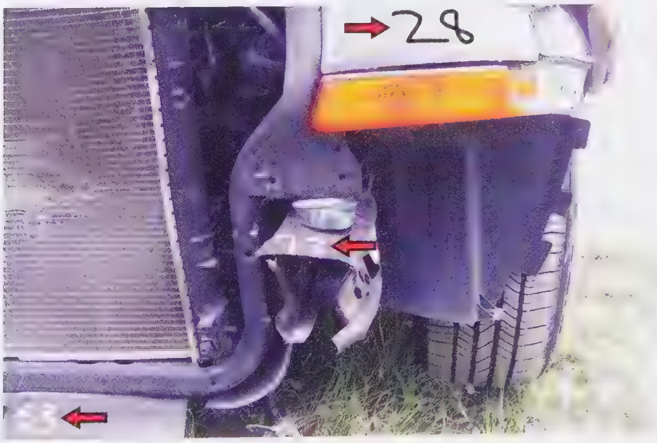


Figure 33-34. *As the estimate is written, each part on the vehicle is assigned a number. This helps keep track of what is included in the estimate.*

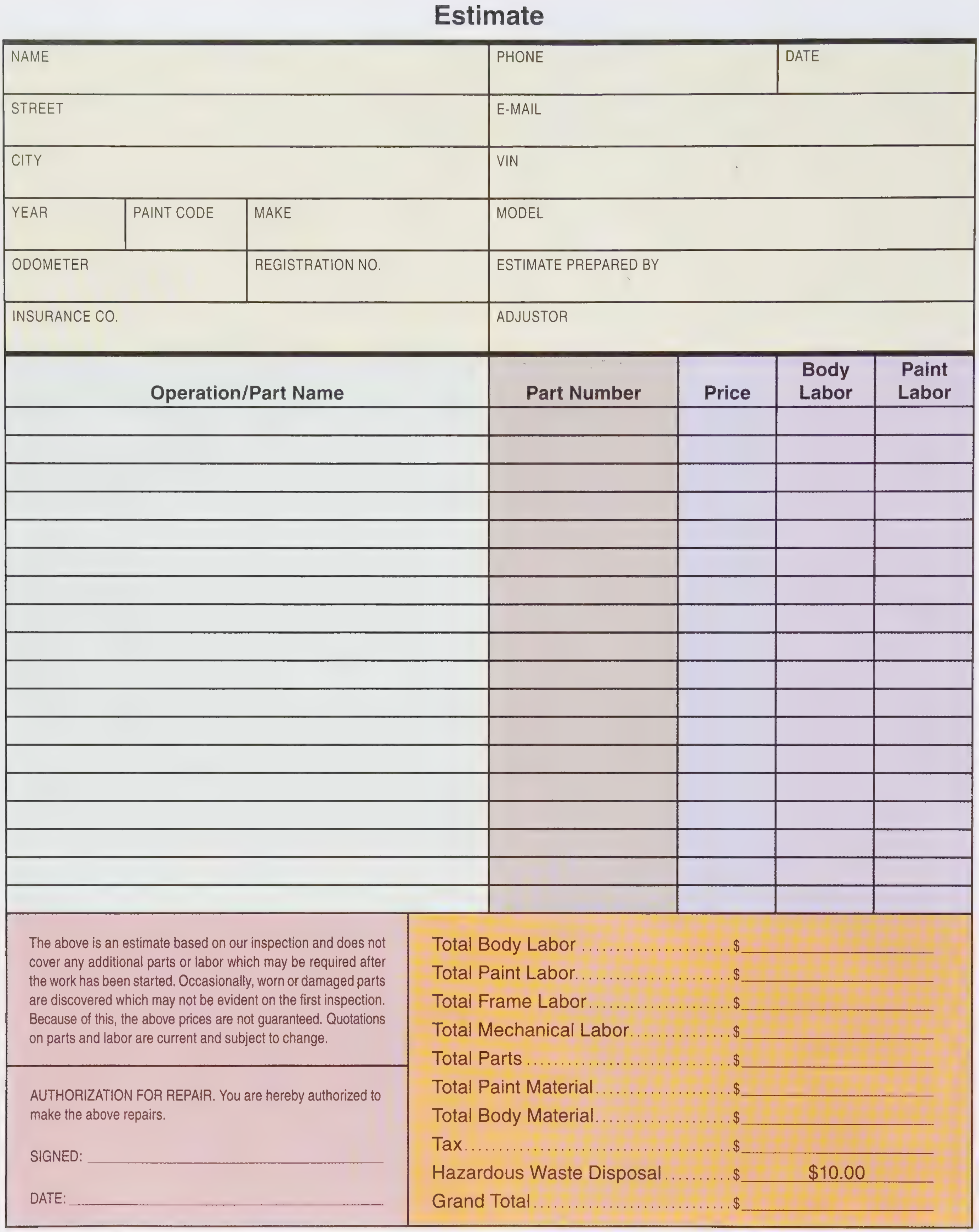
In the totals section of the form, which is colored orange, the body labor hours are multiplied by the body labor rate to calculate the total body labor cost. Paint labor hours are multiplied by the paint labor rate to calculate the total paint labor. Frame labor hours are multiplied by the frame labor rate to calculate the total frame labor. Mechanical labor hours are multiplied by the mechanical labor rate to calculate the total mechanical labor. Part prices are added together and the sum is written in the total parts line. The total paint material cost is calculated by multiplying the total paint labor hours by a refinish factor. The total body material cost is calculated by multiplying the total body repair hours by the body material factor. Tax is calculated by adding the total parts, total paint material, and total body materials together and then multiplying by the state and local sales tax rates. The hazardous waste disposal fee is added to each estimate. To calculate the grand total, add all the lines together.

When completing the estimate, use a separate line for each operation. Write the name of the part and the operation to be performed in the parts column. If the operation involves replacing the part, enter the part number in the parts number column, enter the cost of the part in the price column, enter body labor in the body labor column, and enter paint labor in the paint labor column. Also, enter mechanical or frame labor in the body labor column and use a superscript "m" or "f" to indicate the type of labor.

Computer-Generated Estimate

The goal of computer-generated estimates is to minimize effort by having the computer calculate parts and labor totals, figure overlap, and remind the estimator to include certain operations. The programs used to generate an estimate are set up to include markup, as well as the latest shop labor and sales tax rates. The computer will also prompt the estimator with additional charges. Judgment time for repaired panels can be entered as needed. The computer-generated estimate is stored as an electronic file. The file can be e-mailed to the insurance company or customer, or it can be printed as a professional-looking document.

A computer estimating system must be set up with unique shop criteria before use. During setup, the shop-specific information is entered into the system. Shop specific criteria includes labor rates for body, paint, frame, and mechanical work; factors for paint and body materials; sales tax rates; the threshold for declaring a vehicle a total loss; and aftermarket, salvage yard, and remanufactured parts sources. The database in the estimating systems contains OEM part numbers and prices, body and paint labor allowances, and vehicle values.



Estimate

NAME			PHONE	DATE
STREET			E-MAIL	
CITY			VIN	
YEAR	PAINT CODE	MAKE	MODEL	
ODOMETER		REGISTRATION NO.	ESTIMATE PREPARED BY	
INSURANCE CO.			ADJUSTOR	

Operation/Part Name	Part Number	Price	Body Labor	Paint Labor

The above is an estimate based on our inspection and does not cover any additional parts or labor which may be required after the work has been started. Occasionally, worn or damaged parts are discovered which may not be evident on the first inspection. Because of this, the above prices are not guaranteed. Quotations on parts and labor are current and subject to change.

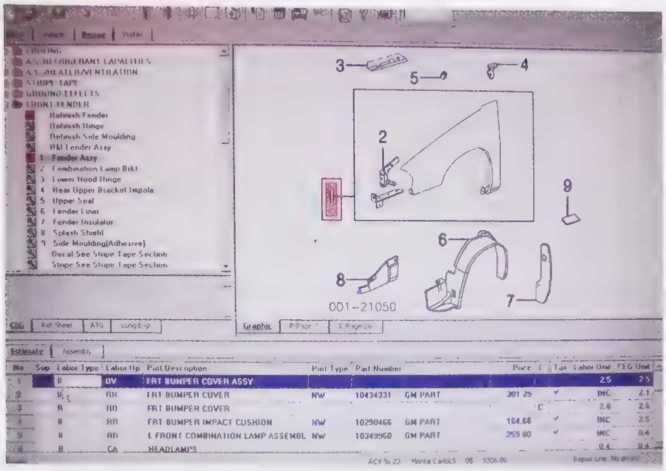
AUTHORIZATION FOR REPAIR. You are hereby authorized to make the above repairs.

SIGNED: ____________________

DATE: ____________________

Total Body Labor .... $____________
Total Paint Labor...................... $____________
Total Frame Labor..................... $____________
Total Mechanical Labor.............. $____________
Total Parts .... $____________
Total Paint Material................... $____________
Total Body Material.................... $____________
Tax....................................... $____________
Hazardous Waste Disposal .... $ $10.00
Grand Total .... $____________

Figure 33-35. *The estimate form has these sections: yellow—header section, green—operation/part, brown—part number, blue—part price, purple—body and paint labor allowances, red—disclaimer section and orange—totals section.*



COOLING
A/C REFRIGERANT CAPACITIES
A/C HEATER/VENTILATION
STRIPE TAPE
GROUND EFFECTS
FRONT FENDER
Refinish Fender
Refinish Hinge
Refinish Side Moulding
R&I Fender Assy
1 Fender Assy
2 Combination Lamp Brkt
3 Lower Hood Hinge
4 Rear Upper Bracket Impala
5 Upper Seal
6 Fender Liner
7 Fender Insulator
8 Splash Shield
9 Side Moulding(Adhesive)
Decal See Stripe Tape Section
Stripe See Stripe Tape Section

No	Sup	Labor Type	Labor Op	Part Description	Part Type	Part Number		Price	Tax	Labor Unit	CEG Unit
1		B	OV	FRT BUMPER COVER ASSY						2.5	2.5
2		B	RR	FRT BUMPER COVER	NW	10434331	GM PART	381.25	✓	INC	2.1
3		B	RO	FRT BUMPER COVER				C		2.6	2.6
4		B	RR	FRT BUMPER IMPACT CUSHION	NW	10290466	GM PART	164.66	✓	INC	2.5
5		B	RR	L FRONT COMBINATION LAMP ASSEMBL	NW	10349960	GM PART	259.80	✓	INC	0.4
6		B	CA	HEADLAMPS						0.4	0.4

ACV % 23 Monte CarloLS 05 3306.06
Repair Line. No errors

Figure 33-36. *This is a screen view of a computerized estimating system. The table of contents is shown in the upper left, the parts section is in the upper right, and the estimate is in the lower half.*

Figure 33-36 shows a screen view captured from a computerized estimating system. The upper left portion of the screen displays a table of contents. The upper right portion looks like a page from a collision estimating guide. The lower half is the estimate, including a listing of parts that will be repaired or replaced. The estimating system is designed to be intuitive and easy to learn.

The estimator enters the VIN into the computer for decoding. From the table of contents, the estimator selects the areas that require repair and works through each screen, selecting parts to be replaced by clicking on the part icon or highlighting the part. Once a part is selected, the part price and labor allowance are automatically displayed on the estimate. The system will prompt the estimator so parts are not overlooked. For example, if a fender is selected, the computer will display a question about fender liner replacement.

If a part will be repaired, the estimator enters the judgment labor allowance. Some estimating systems work from the inside out, and others work from the outside in. A system that works from the inside out anticipates and automatically adds parts to the estimate depending on what the estimator enters. For example, if a lower frame rail is selected by the estimator, the system adds the front bumper assembly and fender. The logic here is that these parts are likely to be damaged if the lower frame rail is damaged. If the system works from the outside in, each part must be added separately because the system does not anticipate any related parts. When all the parts have been added, the estimate is locked, or committed, and no more parts can be added. If a mistake is noticed after the estimate is locked, such as a part left out of the estimate, the estimate must be rewritten because no additions can be made to a locked estimate.

A vehicle hit high on the left front is shown in **Figure 33-37**. The estimate is shown in **Figure 33-38**. Under the *allowance for labor* column, the entry number shows AUTO, indicating an automatic input from the computer, not the estimator. In labor type, REF means refinish labor, BDY means body labor, FRM means frame labor.

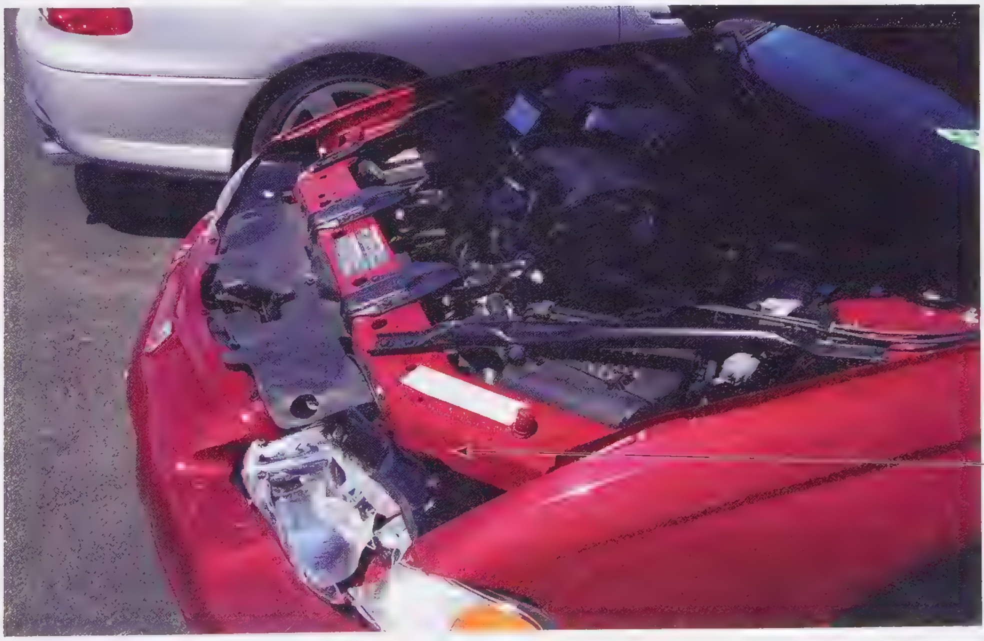

Radiator support damage

Figure 33-37. *The raised hood shows the damage to the radiator support.*

Smash Palace

Quality Collision Repair and Refinishing

Damage Assessed by: Michael Crandell
Description: 2005 Chevrolet Monte Carlo LS
VIN: 2G1WW12E159186872
Insurance Company: ABC

Insured: John Dough
Body Style: 2D Coupe
Drive Train: 3.4 Inj 6 Cyl 4A FWD
Deductible: Unknown

Line Item	Labor Type	Operation	Description	Part Number/ Type	Dollar Amount	Labor Units
1	BDY	O/H	FRT Bumper Cover Assy			2.5
2	BDY	R&R	FRT Bumper Cover	10434331	$381.25	INC #
3	REF	Refinish	FRT Bumper Cover		C	2.6
4	BDY	R&R	FRT Bumper Impact Cushion	10290466	$164.66	INC
5	BDY	R&R	L Front Combination Lamp Assembly	10349960	$259.80	INC
6	BDY	CHK/ADJ	Headlamps			0.4
7	BDY	R&R	Hood Panel	19120222	$546.01	1.0
8	REF	Refinish	Hood Outside		C	2.9
9	REF	Refinish	Hood Underside		C	1.4
10	BDY	R&R	Hood Latch	10352080	$36.20	0.3
11	BDY	R&R	Hood Support	10423490	$18.29	0.3 #
12	REF	Blend	R Fender Outside		C	1.0
13	BDY	R&R	L Fender Panel	89025177	$248.17	1.8 #
14	REF	Refinish	L Fender Outside		C	2.1
15	REF	Refinish	L Fender Edge		C	0.5
16	BDY	Repair	Radiator Support	Existing	C	1.5* #
17	REF	Refinish	Radiator Support			1.5
18	FRM	CHK/ADJ	Measure Frame	Existing		2.0*
19	BDY	R&R	Upper Front Body Air Deflector	10440760	$11.79	0.2
20	REF	Blend	L FRT Door Outside		C	0.9
21	BDY	R&I	L FRT OTR Belt Molding			1.0 #
22	BDY	R&I	L Frt Rearview Mirror			INC #
23	BDY	R&I	L Frt OTR Door Handle			0.3 #
24	BDY*	ADD'L Labor OPR	Clean up prior to delivery	Existing		1.0*
25		ADD'L Cost	Hazardous waste disposal fee		$10.00*	
26	FRM	ADD'L OPR	Frame/Rack setup			1.0*
27	FRM	ADD'L OPR	Unibody Pull			3.0*
28	REF	ADD'L OPR	Clearcoat			2.9
29	REF*	ADD'L OPR	Restore Corrosion Protection			0.5*
30	REF	ADD'L OPR	Finish Sand and Buff			2.0
31		ADD'L Cost	Paint/Materials			423.80*

* – Judgment Item # – Labor Note Applies C – Included in Clearcoat Calculation

(Continued)

Figure 33-38. *The estimate shows customer information as well as a checklist of what will be fixed.*

Estimate Totals

Labor Subtotals

	Units	Rate	Add'l Labor Amount	Sublet Amount	Totals
Body	10.3	$46.00	$0.00	$0.00	$473.80 T
Refinish	18.3	$46.00	$0.00	$0.00	$841.80 T
Frame	6.0	$56.00	$0.00	$0.00	$336.00 T
		Taxable Labor			$1,651.60
Labor Summary	34.6				$1,651.60

Part Totals

Taxable Parts	$1,666.17
Sales Tax @ 6.25%	$104.13
Total Replacement Parts Amount	$1,770.30

Additional Costs

Taxable Costs	$433.80
Sales Tax @ 6.25%	$27.11
Total Additional Costs	$460.91

Adjustments

Customer Responsibility	$0.00
Total Labor	$1,651.60
Total Replacement Parts	$1,770.30
Total Additional Costs	$460.91
Gross Total	$3,882.81

Total Adjustments

Adjustments	$0.00
Net Total	**$3,882.81**

This is a preliminary estimate. Additional changes to the estimate may be required for the actual repair.

Figure 33-38. *Continued.*

Summary

- All autobody repairs start with an estimate.
- Always treat the customer and the vehicle with respect.
- The customer's choice of shop is determined by the impression created by the estimator.
- Damage to a vehicle is called a loss by an insurance company.
- The ability to inspect and analyze the damage are the most essential skills for an estimator.
- Rapid deceleration and the weight of the drive train may cause motor mount brackets to bend.
- Deciding whether to repair or replace a damaged part should come only after careful inspection.
- Always suspect hidden damage when you study the damaged area.
- An estimator must understand all the steps needed to return the vehicle to pre-accident condition.
- An estimator must have knowledge of parts sources.
- OEM parts are the same as the parts installed on the vehicle when it was manufactured.
- Used parts or recycled parts are obtained from salvaged vehicles.
- Remanufactured parts are damaged or worn parts that have been repaired to OEM specifications.

- Understanding labor and how to charge for it is essential to the survival of the shop.
- There are two types of labor: flat rate for panel replacement, and judgment for panel repair.
- Repair labor is also called judgment labor.
- Labor not listed in the flat rate manual and not part of judgment time is called additional labor.
- A body shop has two sources of income: selling technician labor and selling parts.
- The source of parts is the biggest influence on how much they will cost.
- Material prices are figured separately from part prices.
- Additional damage may be discovered as the vehicle is disassembled during repair. Any additional parts or labor not on the original estimate are considered add-ons.
- A computer-generated estimate minimizes effort by having the computer calculate parts and labor totals, figure overlap, and remind the estimator to include certain operations.

Review Questions

Please do not write in this textbook. Place your answers on a separate sheet of paper.

1. An insurance company must pay for the repair of a damaged vehicle. This is called a(n) ______.
2. The ______ is an identification code. It contains an identification number, paint code, and trim code.
3. Define the repair procedure R&I.
4. A(n) ______ part is manufactured by an independent manufacturer, not the one that made the OEM part. As a rule, these parts cost less than OEM parts.
5. An estimator must know the names of the vehicle's parts, both body and mechanical. Major parts, which are made up of several smaller parts are referred to as a(n) ______.
6. The estimator should sell the repair to the customer. True or False?
7. Often, the customer's choice of shop is determined by the impression created by the estimator. True or false?
8. The cost of a new fender is $190.00. The cost of repair is $125.00. The fender should be replaced. True or False?
9. A rear clip includes the roof. True or False?
10. A damaged door panel will be repaired from the outside. There are four units of damage. The door handle must be removed. Access time is 1.5 hours. What is the total repair time?
11. A quarter panel dent includes a bodyline. The damage is the size of three credit cards. One half hour is required to R&I the trunk liner and vehicle jack. What is the labor allowance?
12. A frame has kickup damage on one rail. What is the total frame repair allowance, including measuring and set up?
13. What is the labor allowance to blend a hood if the paint time for the hood is 2.8 hours?
14. What is the clearcoat labor allowance for a door with 2.2 hours of paint time?
15. A body shop pays $500 for a used door assembly. How much does the shop charge the customer?
16. A(n) ______ rate is an established amount of time, listed in hours and tenths of an hour, to perform a specified replacement or refinish task.
17. Left and right part numbers are listed as 327858-9. What is the part number of the left part?
18. ______ is deducted from labor times when replacing one component makes it easier to replace another component, or when replacing one component is part of another operation.
19. The shop's paint materials factor is $28 per refinish hour. There are twenty hours of paint labor. How much does the shop charge the customer for paint materials?
20. The sales tax rate on parts and paint materials is 6.25%. The parts cost is $150. The paint material cost is $50. How much sales tax is charged to the customer?

ASE-Style Questions

1. Technician A says that the customer should be treated with respect. Technician B says the customer is always interested in only the dollar amount of the repair. Who is right?
   (A) A only.
   (B) B only.
   (C) Both A and B.
   (D) Neither A nor B.
2. When estimating a vehicle with sidesway on both front rails, Technician A says the vehicle should be put on a lift to check for under vehicle damage. Technician B says that leaking oil is a sign of engine damage. Who is right?
   (A) A only.
   (B) B only.
   (C) Both A and B.
   (D) Neither A nor B.

3. A new fender will be installed on a vehicle. Technician A says this is called R&I. Technician B says this is called R&R. Who is right?
   (A) A only.
   (B) B only.
   (C) Both A and B.
   (D) Neither A nor B.
4. All of the following are abbreviations used to indicate a repair procedure EXCEPT:
   (A) D&R.
   (B) R&I.
   (C) A&W.
   (D) "m."
5. A notation for a part in a collision-estimating guide is IOH. Technician A says this means that no additional labor needs to be charged for this part. Technician B says that it means "included in overhaul." Who is right?
   (A) A only.
   (B) B only.
   (C) Both A and B.
   (D) Neither A nor B.
6. Technician A says that repairs listed with an "m" are charged at a higher labor rate than body repairs. Technician B says that R&R of the condenser includes evacuation and recharge. Who is right?
   (A) A only.
   (B) B only.
   (C) Both A and B.
   (D) Neither A nor B.
7. Which of the following assemblies includes the roof?
   (A) Side clip.
   (B) Front clip.
   (C) Rear clip top.
   (D) Rear clip.
8. A new OEM hood will be installed on a vehicle. Technician A says that the paint labor time for the hood includes the underside of the hood. Technician B says that additional labor time must be added to edge the hood. Who is right?
   (A) A only.
   (B) B only.
   (C) Both A and B.
   (D) Neither A nor B.
9. A door panel will be blended. Technician A says to calculate blend time, multiply the door paint time by 0.6 hour. Technician B says that clearcoat time must be figured in the door. Who is right?
   (A) A only.
   (B) B only.
   (C) Both A and B.
   (D) Neither A nor B.
10. A damaged quarter panel has one unit of damage. There is a body line. Access time inside the trunk is 0.5 hour. What is the repair time?
    (A) 1.0 hour.
    (B) 1.5 hours.
    (C) 2.0 hours.
    (D) 2.5 hours.
11. A frame has sidesway on both rails. One rail has sag. What is the total frame repair time? (Refer to **Figure 33-31**)
    (A) 6 hours.
    (B) 9 hours.
    (C) 12 hours.
    (D) 15 hours.
12. The shop charges $28/paint hour for materials. The repair has 7.5 hours of paint labor. The cost of paint materials is
    (A) $200.00.
    (B) $205.00.
    (C) $210.00.
    (D) $215.00.
13. All of the following are additional materials EXCEPT:
    (A) fasteners.
    (B) primer.
    (C) plastic repair material.
    (D) body side molding tape.
14. The tow bill to bring a damaged vehicle to a body shop is $125. How much does the body shop charge the customer, considering a 25% markup?
    (A) $156.25.
    (B) $163.50.
    (C) $165.30.
    (D) $167.50.
15. The parts and paint cost for a repair is $150. The tax rate is 7.25%. What is the sales tax?
    (A) $0.10.
    (B) $1.08.
    (C) $10.88.
    (D) $108.80.

This painter is certified as an ASE refinishing technician. He passed the ASE Painting and Refinishing test (B2), and has two years of relevant, full-time, hands-on work experience. (Shutterstock)

Chapter 34

ASE Certification

Objectives

After studying this chapter, you will be able to:

- Explain the value of ASE certification.
- Understand how to answer ASE style questions.
- List the steps to become ASE certified.

Technical Terms

ASE collision repair technician
ASE master collision repair/refinishing technician
ASE refinishing technician
incomplete sentence questions
National Automotive Technicians Education Foundation (NATEF)
National Institute for Automotive Service Excellence (ASE)
negative questions
one-part question
two-part questions
Work Experience Reporting Form

Introduction

The technology of collision repair has come a long way in a short time. Today's sophisticated finishes, for example, are very different from the enamel and lacquer paints used by automobile manufacturers just a few years ago. How can a customer be sure that a collision repair shop has kept up with ever-changing technology and is qualified to bring a vehicle back to pre-accident condition—both structurally and in terms of appearance? ASE certification is a nationally recognized symbol of competence. A collision repair shop that displays the ASE blue seal logo employs technicians that are knowledgeable, experienced professionals.

What Is ASE Certification?

The ***National Institute for Automotive Service Excellence,*** or ***ASE***, is a nonprofit organization that offers a voluntary testing program for automotive technicians. A technician who passes an ASE test and has the required experience is awarded ASE certification program accreditation.

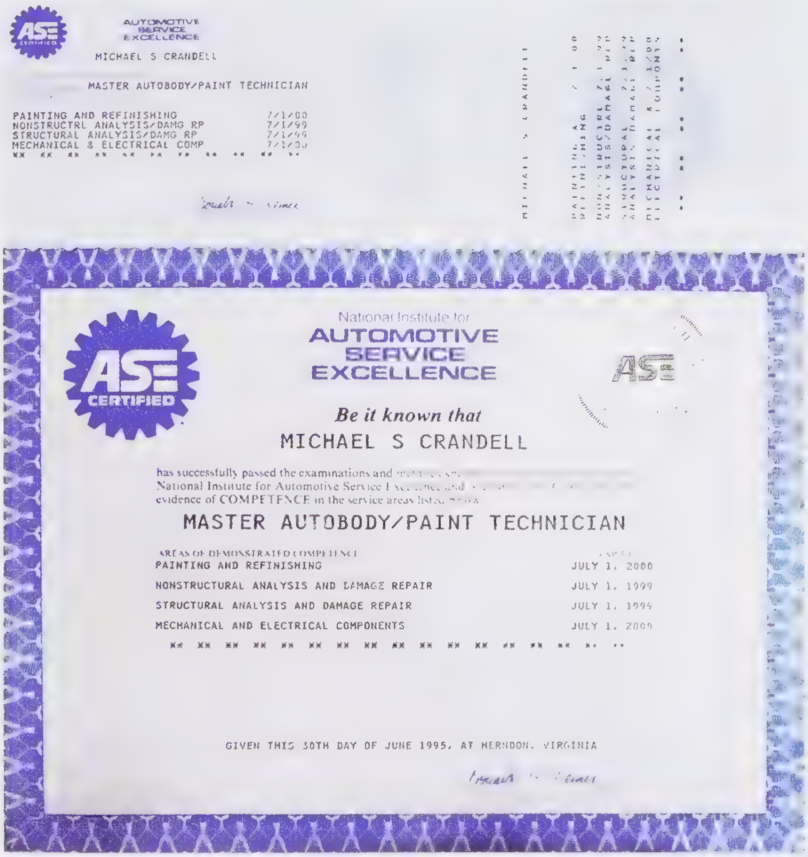
Anyone can call themselves a collision repair technician, whether they possess the skills and knowledge to make acceptable repairs or not. However, an ASE-certified technician has taken the time and has the interest to demonstrate competency in at least one ASE area.

ASE was founded in 1972. Today, more than 350,000 automotive technicians hold ASE certification. The number of tests has increased and probably will increase in the future. At this time, the following collision repair and refinishing tests are offered:

- Painting and Refinishing (Test B2).
- Nonstructural Analysis and Damage Repair (Test B3).
- Structural Analysis and Damage Repair (Test B4).
- Mechanical and Electrical Components (Test B5).
- Damage Analysis and Estimating (Test B6).

If you pass one or more of these tests and meet the required experience requirements, you will be certified as an ***ASE collision repair technician*** or as an ***ASE refinishing technician***. An individual who passes all five collision repair and refinishing tests is certified as an ***ASE master collision repair/refinishing technician***. See **Figure 34-1**.

ASE certification means that a school meets the requirements for equipment, curriculum, and instructors. A school that has ASE certification follows guidelines that are proven to develop competent technicians.



AUTOMOTIVE
SERVICE
EXCELLENCE
MICHAEL S CRANDELL

MASTER AUTOBODY/PAINT TECHNICIAN

PAINTING AND REFINISHING 7/1/00
NONSTRUCTRL ANALYSIS/DAMG RP 7/1/99
STRUCTURAL ANALYSIS/DAMG RP 7/1/99
MECHANICAL & ELECTRICAL COMP 7/1/00
** ** ** ** ** ** ** ** ** ** **

National Institute for
AUTOMOTIVE
SERVICE
EXCELLENCE

Be it known that
MICHAEL S CRANDELL
has successfully passed the examinations and [illegible]
National Institute for Automotive Service Excellence and [illegible]
evidence of COMPETENCE in the service areas listed [illegible]

MASTER AUTOBODY/PAINT TECHNICIAN

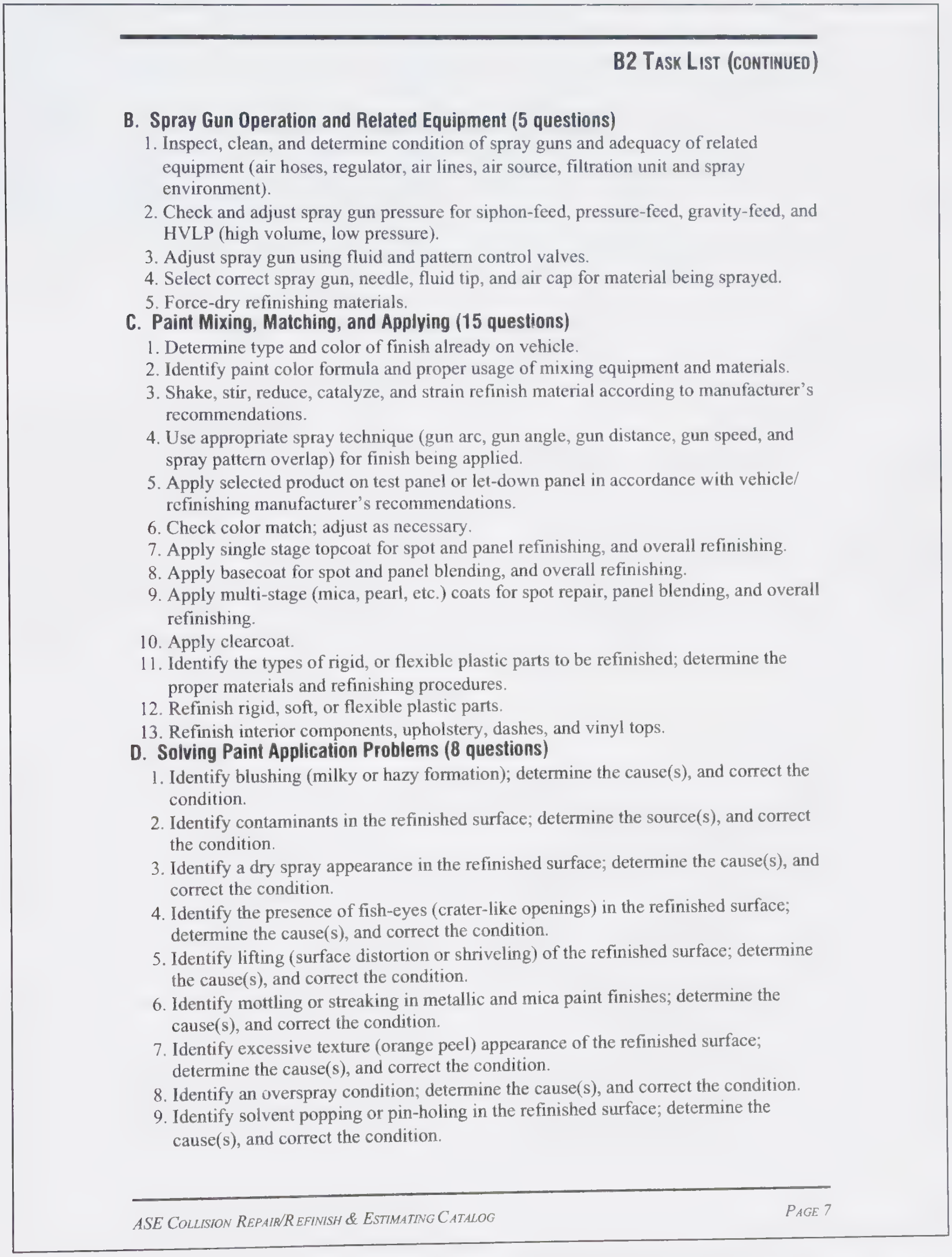
AREAS OF DEMONSTRATED COMPETENCE	[illegible]
PAINTING AND REFINISHING	JULY 1, 2000
NONSTRUCTURAL ANALYSIS AND DAMAGE REPAIR	JULY 1, 1999
STRUCTURAL ANALYSIS AND DAMAGE REPAIR	JULY 1, 1999
MECHANICAL AND ELECTRICAL COMPONENTS	JULY 1, 2000

** ** ** ** ** ** ** ** ** ** ** ** ** ** ** ** **

GIVEN THIS 30TH DAY OF JUNE 1995, AT HERNDON, VIRGINIA

Figure 34-1. *This is the ASE Master Autobody/Paint Technician certificate of Collision Repair and Refinishing author Michael Crandell.*

ASE also promotes education by helping to develop the standards for automotive repair training programs. A branch of ASE, known as the ***National Automotive Technicians Education Foundation (NATEF)***, sets standards and educational priorities. NATEF has established a list of tasks. This task list serves as a solid base for course-of-study outlines and accurately describes the school's training programs. The task list is developed by panels of technical service experts from the automotive service industry and vocational education. **Figure 34-2** shows one portion of this task list. This textbook was organized to teach these tasks.



B2 Task List (continued)

B. Spray Gun Operation and Related Equipment (5 questions)

1. Inspect, clean, and determine condition of spray guns and adequacy of related equipment (air hoses, regulator, air lines, air source, filtration unit and spray environment).
2. Check and adjust spray gun pressure for siphon-feed, pressure-feed, gravity-feed, and HVLP (high volume, low pressure).
3. Adjust spray gun using fluid and pattern control valves.
4. Select correct spray gun, needle, fluid tip, and air cap for material being sprayed.
5. Force-dry refinishing materials.

C. Paint Mixing, Matching, and Applying (15 questions)

1. Determine type and color of finish already on vehicle.
2. Identify paint color formula and proper usage of mixing equipment and materials.
3. Shake, stir, reduce, catalyze, and strain refinish material according to manufacturer's recommendations.
4. Use appropriate spray technique (gun arc, gun angle, gun distance, gun speed, and spray pattern overlap) for finish being applied.
5. Apply selected product on test panel or let-down panel in accordance with vehicle/refinishing manufacturer's recommendations.
6. Check color match; adjust as necessary.
7. Apply single stage topcoat for spot and panel refinishing, and overall refinishing.
8. Apply basecoat for spot and panel blending, and overall refinishing.
9. Apply multi-stage (mica, pearl, etc.) coats for spot repair, panel blending, and overall refinishing.
10. Apply clearcoat.
11. Identify the types of rigid, or flexible plastic parts to be refinished; determine the proper materials and refinishing procedures.
12. Refinish rigid, soft, or flexible plastic parts.
13. Refinish interior components, upholstery, dashes, and vinyl tops.

D. Solving Paint Application Problems (8 questions)

1. Identify blushing (milky or hazy formation); determine the cause(s), and correct the condition.
2. Identify contaminants in the refinished surface; determine the source(s), and correct the condition.
3. Identify a dry spray appearance in the refinished surface; determine the cause(s), and correct the condition.
4. Identify the presence of fish-eyes (crater-like openings) in the refinished surface; determine the cause(s), and correct the condition.
5. Identify lifting (surface distortion or shriveling) of the refinished surface; determine the cause(s), and correct the condition.
6. Identify mottling or streaking in metallic and mica paint finishes; determine the cause(s), and correct the condition.
7. Identify excessive texture (orange peel) appearance of the refinished surface; determine the cause(s), and correct the condition.
8. Identify an overspray condition; determine the cause(s), and correct the condition.
9. Identify solvent popping or pin-holing in the refinished surface; determine the cause(s), and correct the condition.

ASE Collision Repair/Refinish & Estimating Catalog *Page 7*

Figure 34-2. *The ASE works with collision repair industry professionals to develop a relevant task list for virtually any job a technician can be expected to perform.*

Why Should You Become ASE Certified?

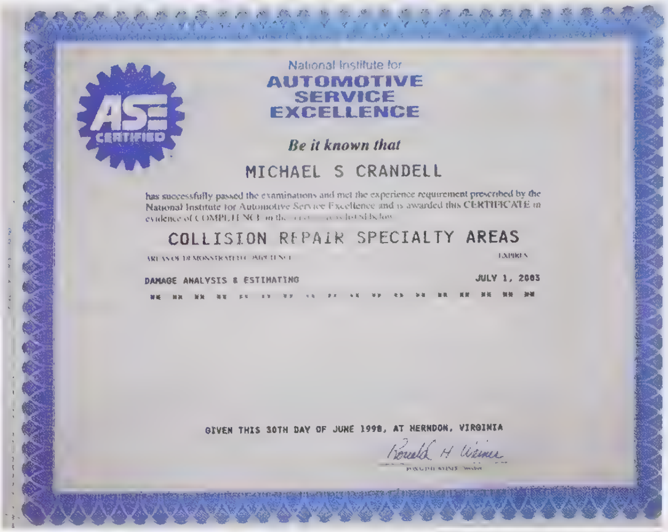
ASE certification is the standard of the automotive repair industry. A certified technician is recognized as a being proficient in the areas of certification. ASE certification may help a technician obtain a job. All automotive technicians are encouraged to become ASE certified.

Not only will ASE certification help a technician obtain a job, but it may also help the shop attract customers. Often a shop will display its technicians' ASE certificates. See **Figure 34-3**. These certificates show customers that the shop's technicians have demonstrated competency in specific areas. By seeing that the shop's technicians are ASE certified, the customer will feel more confident that repairs will be made correctly.

How Do I Become ASE Certified?

The first requirement for ASE certification is hands-on work experience. Normally, two years of relevant, full-time, hands-on work experience is required for B2, B3, B4 and B5. Two years of experience specifically related to damage analysis and estimating is required for ASE certification as a collision damage estimator (B6). See **Figure 34-4**. However, three years of high school collision repair training or two years of post-secondary collision repair training may be substituted for one year of the hands-on work experience. Other substitutions, such as completion of an apprenticeship or co-op program, may be allowed for the entire two years of hands-on work experience. Additional substitutions may be allowed; contact ASE for details.

Figure 34-3. *ASE certification is the standard of the automotive repair industry. Collision repair shops often display their technicians' certificates as a way to demonstrate the shop's competency and professionalism.*



National Institute for
AUTOMOTIVE
SERVICE
EXCELLENCE

Be it known that

MICHAEL S CRANDELL

has successfully passed the examinations and met the experience requirement prescribed by the National Institute for Automotive Service Excellence and is awarded this CERTIFICATE in evidence of COMPETENCE in the [illegible] listed below

COLLISION REPAIR SPECIALTY AREAS

AREAS OF DEMONSTRATED COMPETENCE EXPIRES

DAMAGE ANALYSIS & ESTIMATING JULY 1, 2003

GIVEN THIS 30TH DAY OF JUNE 1998, AT HERNDON, VIRGINIA

Ronald H Weiner

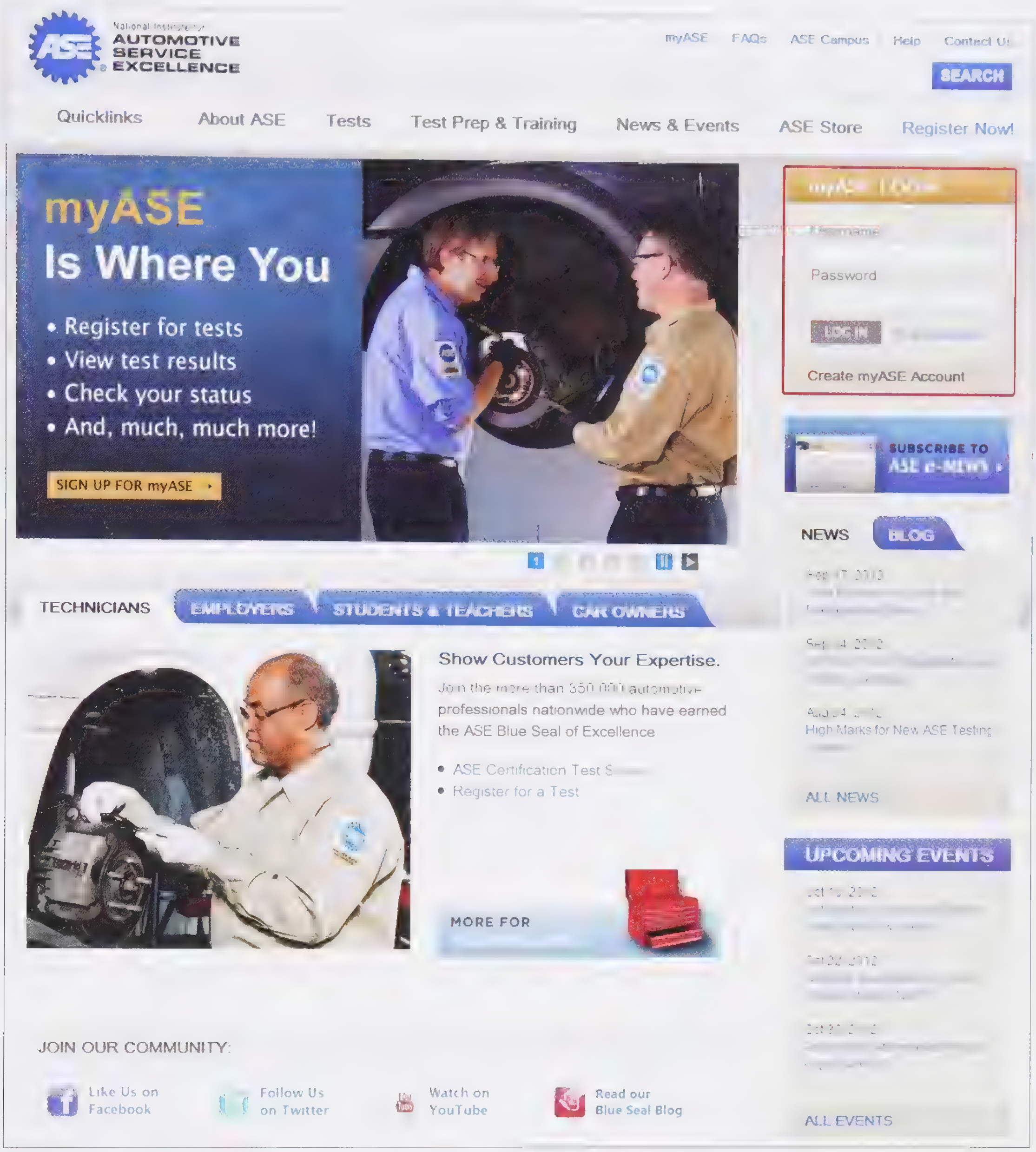
Figure 34-4. *A separate ASE certificate is issued for Damage Analysis & Estimating. This is the author's certificate.*

When you register for the tests, you will receive a form called a ***Work Experience Reporting Form*** on which to list work experience. It is available online and can be filled out anytime after you register for the test. If you pass the test, or tests, and submit the documentation for hands-on work experience, you will be ASE certified. If you do not have the required work experience, but pass a test, you will not be ASE certified until you fulfill the work experience requirement.

The ASE test is computer-based. Each test has a one- to two-hour time limit. An extra half hour is included to allow enough time for check-in, a pre-test tutorial, and a post-test survey. Each test begins with a short tutorial to help familiarize the technician with the computer-based exam. Every question has one right answer, three wrong answers, and enough information to choose the right answer. In the past, it took six to eight weeks after taking the test to receive a pass/fail notice. Now, with the computer-based testing, you will know if you passed before leaving the test center.

The procedure for obtaining ASE certification as follows:

1. You can either download a form or request printed materials on the ASE website. See **Figure 34-5**.


National Institute for AUTOMOTIVE SERVICE EXCELLENCE
myASE
FAQs
ASE Campus
Help
Contact Us
SEARCH
Quicklinks
About ASE
Tests
Test Prep & Training
News & Events
ASE Store
Register Now!
myASE
Is Where You
SIGN UP FOR myASE
myASE LOGIN
Username
Password
LOG IN
Create myASE Account
SUBSCRIBE TO ASE e-NEWS
NEWS
BLOG
TECHNICIANS
EMPLOYERS
STUDENTS & TEACHERS
CAR OWNERS
MORE FOR
ALL NEWS
UPCOMING EVENTS
ALL EVENTS
JOIN OUR COMMUNITY:
Like Us on Facebook
Follow Us on Twitter
Watch on YouTube
Read our Blue Seal Blog

- Register for tests
- View test results
- Check your status
- And, much, much more!

Show Customers Your Expertise.

Join the more than 350,000 automotive professionals nationwide who have earned the ASE Blue Seal of Excellence

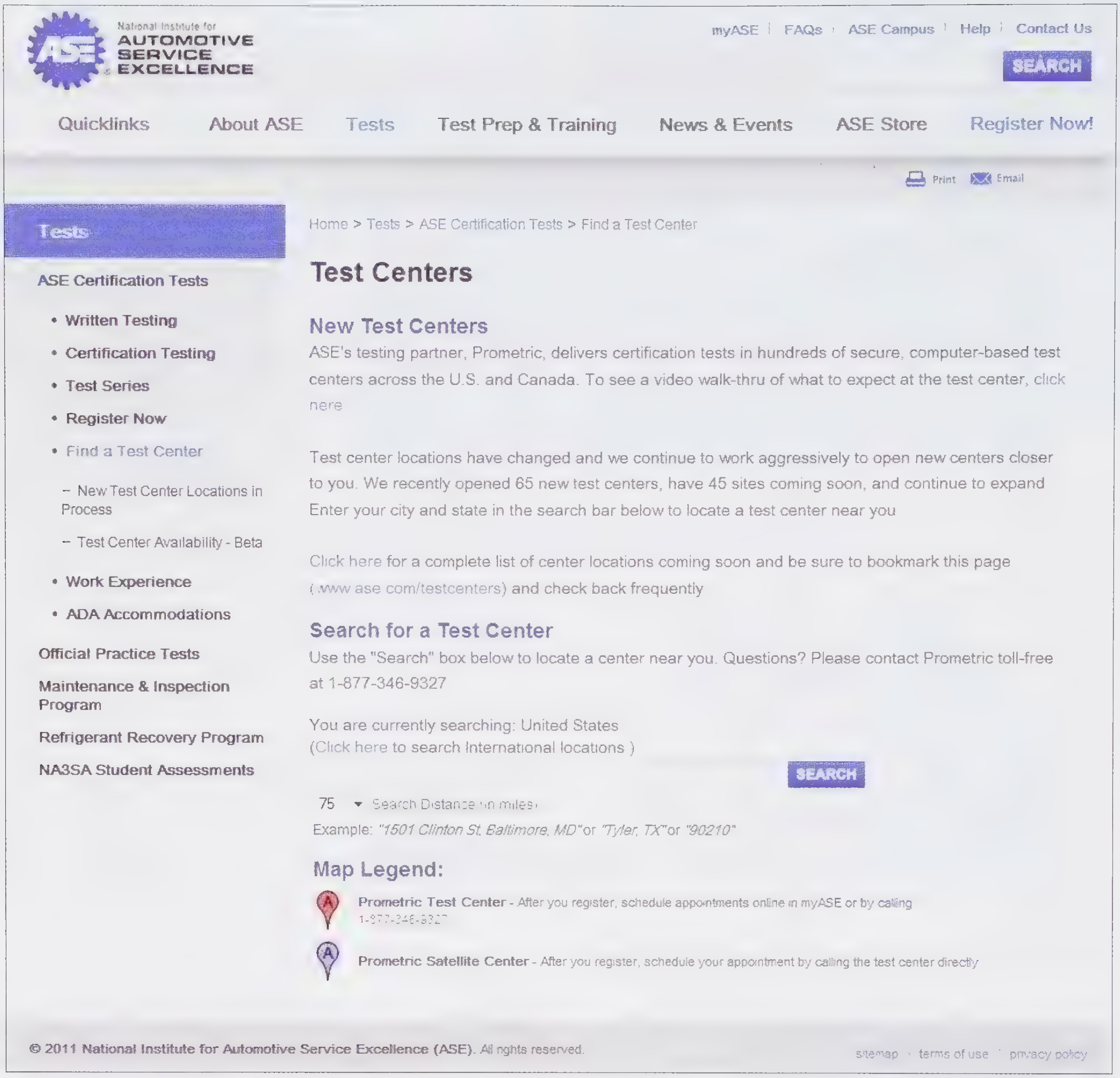
- ASE Certification Test S
- Register for a Test

High Marks for New ASE Testing

Figure 34-5. *The ASE website guides you through the certification process. Registering for a certification test is as easy as clicking a mouse.*

2. Decide on which tests you want to take and locate the nearest test center. **Figure 34-6** shows how easy it is to find the nearest test center.
3. You must set up an account; visit the ASE website for details. Fill out and submit the test registration form and fee. The Work Experience Reporting Form can be filled out after you register for the test.
4. Practice tests and study guides are available from various publishers. Sample questions are included in the registration booklet. This textbook also has ASE-style questions at the end of each chapter.
5. After registration, you will receive a registration ticket and instructions. Review the test information prior to the test.
6. Take the test during the designated time frame. All you need to bring to the test center is your registration ticket and current, government-issue photo ID. Books, calculators, and other reference materials are not permitted in the test room.

ASE certification is good for five years. Once five years have passed, the technician must take a recertification test to remain certified. The recertification test has about half the number of questions of a regular certification test. Recertification is also good for five years.


National Institute for
AUTOMOTIVE
SERVICE
EXCELLENCE
myASE
FAQs
ASE Campus
Help
Contact Us
SEARCH
Quicklinks
About ASE
Tests
Test Prep & Training
News & Events
ASE Store
Register Now!
Print
Email
Tests
ASE Certification Tests
Written Testing
Certification Testing
Test Series
Register Now
Find a Test Center
New Test Center Locations in Process
Test Center Availability - Beta
Work Experience
ADA Accommodations
Official Practice Tests
Maintenance & Inspection Program
Refrigerant Recovery Program
NA3SA Student Assessments
Home > Tests > ASE Certification Tests > Find a Test Center
SEARCH
75
Search Distance (in miles)
sitemap
terms of use
privacy policy

Test Centers

New Test Centers

ASE's testing partner, Prometric, delivers certification tests in hundreds of secure, computer-based test centers across the U.S. and Canada. To see a video walk-thru of what to expect at the test center, click here

Test center locations have changed and we continue to work aggressively to open new centers closer to you. We recently opened 65 new test centers, have 45 sites coming soon, and continue to expand Enter your city and state in the search bar below to locate a test center near you

Click here for a complete list of center locations coming soon and be sure to bookmark this page (www.ase.com/testcenters) and check back frequently

Search for a Test Center

Use the "Search" box below to locate a center near you. Questions? Please contact Prometric toll-free at 1-877-346-9327

You are currently searching: United States
(Click here to search International locations)

Example: *"1501 Clinton St. Baltimore, MD"* or *"Tyler, TX"* or *"90210"*

Map Legend:

Prometric Test Center - After you register, schedule appointments online in myASE or by calling 1-877-346-9327

Prometric Satellite Center - After you register, schedule your appointment by calling the test center directly

© 2011 National Institute for Automotive Service Excellence (ASE). All rights reserved.

Figure 34-6. *ASE offers certification tests in hundreds of secure, computer-based test centers across the U.S. and Canada. Go to www.ASE.com and click on Find a Test Center.*

What Are the ASE Tests Like?

There are five ASE certification tests: four for collision repair and refinishing, and one for damage analysis and estimating. A test is divided into individual subject areas. Each subject area has several questions.

Figure 34-7 shows the breakdown of subject areas. All questions on ASE certification tests are multiple choice questions. These questions can be grouped into four broad categories: one-part questions, two-part questions, negative questions, and incomplete sentence questions. Each type of question is explained in this section.

ASE Test Specifications and Task Lists

Painting and Refinishing (Test B2)

Content Area	Questions in Test
Surface Preparation	16
Spray Gun Operation and Related Equipment	5
Paint Mixing, Matching, and Applying	15
Solving Paint Application Problems	8
Finish Defects, Causes, and Cures	6
Safety Precautions and Miscellaneous	5
Total	**55**

Non-Structural Analysis and Damage Repair (Test B3)

Content Area	Questions in Test
Preparation	5
Outer Body Panel Repairs, Replacements and Adjustments	18
Metal Finishing and Body Filling	9
Glass and Hardware	5
Welding and Cutting	12
Plastic Repair	6
Total	**55**

Structural Analysis and Damage Repair (Test B4)

Content Area	Questions in Test
Frame Inspection and Repair	13
Unibody Inspection, Measurement, and Repair	20
Stationary Glass	4
Metal Welding and Cutting	13
Total	**50**

Mechanical and Electrical Components (Test B5)

Content Area		Questions in Test
Suspension and Steering		11
Electrical		9
Brakes		5
Heating and Air Conditioning		5
Engine Cooling Systems		4
Drive Train		5
Fuel, Intake, and Exhaust Systems		3
Restraint systems		8
1. Active Restraint systems	(2)	
2. Passive Restraint systems	(2)	
3. Supplemental Restraint systems (SRS)	(4)	
Total		**50**

Damage Analysis and Estimating (Test B6)

Content Area		Questions in Test
Damage Analysis		11
Estimating		14
Legal and Environmental Practices		2
Vehicle Construction		6
Vehicle Systems Knowledge		11
1. Fuel, Intake, Ingition, and Exhaust Systems	(1)	
2. Suspension, Steering, and Powertrain	(3)	
3. Brakes	(1)	
4. Heating, Engine Cooling and Air Conditioning	(2)	
5. Electrical/Electronic Systems	(1)	
6. Safety Systems	(2)	
7. Fasteners and Materials	(1)	
Parts Identification and Source		4
Customer Relations and Sales Skills		2
Total		**50**

Figure 34-7. *Each of the five ASE certification tests is further divided into individual subject areas, which are described above.*

One-Part Questions

A ***one-part question*** requires that the technician answer with a single fact. For example:

Which of the following paint defects is best described as craters in newly applied paint?
(A) Solvent pop.
(B) Lifting.
(C) Sand scratch swelling.
(D) Chalking.

To answer this type of question, read each answer to see if any make sense. Then, compare the answers that do make sense to see which answer is best. For this question, answer D does not make sense. Chalking is a problem in old, weathered paint, not newly applied paint. The remaining answers are potential problems in new paint. Lifting looks like wrinkles in the paint, not craters. Sand scratch swelling looks like tiny furrows in the paint, not craters. Solvent pop is caused by reducer or thinner evaporating from a partially cured paint surface, causing small craters. The answer is A, Solvent pop.

Two-Part Questions

ASE tests use Technician A and Technician B in ***two-part questions***. Both Technicians make a statement, perform a task, or evaluate a situation. To answer the question, read what Technician A does or says and read what Technician B does or says. In the answer, Technician A could be right (A only), Technician B could be right (B only), both technicians could be right (Both A and B), or both technicians could be wrong (Neither A nor B). The following is an example of a two-part question:

When installing a hood, Technician A first checks the gap between the fenders and the hood. Technician B checks the gap between the cowl and the hood first. Who is right?
(A) A only.
(B) B only.
(C) Both A and B.
(D) Neither A nor B.

This type of question can be thought of as a combination of two true/false questions. Read each technician's actions or comments. Decide if either statement is true. In this example, answer B, and B only, is correct. The gap at the cowl and the hood should be checked first, as it will show whether or not the hood is square in the hood opening.

Negative Questions

Negative questions are commonly used in ASE certification tests. A negative question contains the words *except*, *not*, *least likely*, or *most likely*. In this type of question, a statement is made and four answers are given. You must identify the answer that does not agree with the statement. This is the exception. The following is an example of a negative question:

All the following abrasives can be used to prep for a clearcoat blend EXCEPT:
(A) 40-grit sandpaper.
(B) 1000-grit wet sandpaper.
(C) 800-grit dry sandpaper.
(D) gray scuff pad and sanding paste.

Carefully read over each answer and determine which statements are true and which one is the exception. For this question, answers B, C, and D are all acceptable methods of preparing clearcoat for a blend. Answer (A), 40-grit sandpaper, is not. Using 40-grit sandpaper would cause deep grooves in the clearcoat. Therefore, 40-grit sandpaper would never be used when preparing for a clearcoat blend.

Incomplete Sentence Questions

Incomplete sentence questions are also called fill-in-the-blank questions. The technician picks the answer that best fills in the blank. For example:

A ______ is the best tool to use when finish sanding a 16" x 16" patch of cured body filler.
(A) grinder
(B) mudhog
(C) dual-action sander
(D) long board

To answer this question, read over each answer to see if it is true. A grinder should not be used to finish sand, nor should a mudhog. Some technicians use a dual-action sander, but in a large area such as this, a dual-action sander would tend to cut waves in the filler. The best answer is D, long board.

Always read each answer carefully before making your choice. If there is a question that you cannot answer, skip it and come back to it later.

Summary

- An ASE-certified technician has demonstrated competency in the specific test area.
- ASE certification is the standard of competency in the automotive repair industry.
- ASE certifies automotive repair education programs. NATEF sets certification standards.
- A technician who does not graduate from an ASE certified education program must have two years of collision repair experience and pass the tests to become certified.
- All autobody repair technicians should become certified.
- ASE certification is good for five years. Once five years have passed, the technician must take a recertification test to remain certified.
- There are five ASE certification tests: four for collision repair and refinishing, and one for damage analysis and estimating.
- Always read each answer carefully before making your choice.

Review Questions

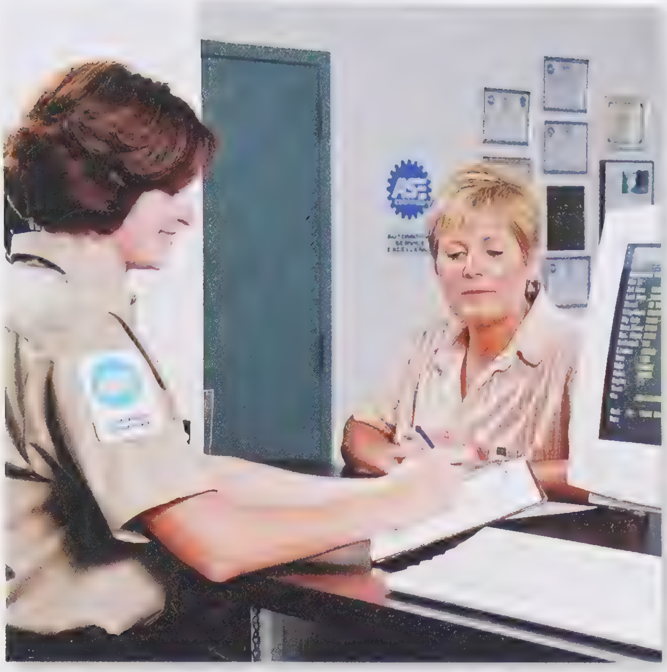
Please do not write in this textbook. Place your answers on a separate sheet of paper.

1. The National Institute for Automotive Service Excellence, or ASE, is a non-profit organization that offers a voluntary ______ program for automotive technicians.
2. A collision repair shop that displays the ASE blue seal logo employs technicians that are knowledgeable, experienced professionals. True or False?
3. There are five ASE certification tests: four for ______, and one ______.
4. ASE was founded in 1972. Today, more than 350,000 automotive technicians hold ASE certification. True or False?
5. The task list created by the National Automotive Technicians Education Foundation (NATEF) was developed by panels of technical service experts from the automotive service industry and vocational education. True or False?
6. Passing an ASE test and ______ years of collision repair experience are required for certification.
7. ______ is required five years after initial ASE certification.
8. An ASE master collision repair/refinishing technician has passed which tests?
9. ______ years of experience, specifically related to damage analysis and estimating, are required for ASE certification as a collision damage estimator.
10. Why should you become ASE certified?

ASE-Type Questions

1. Technician A says that ASE offers four certification tests in Collision Repair and Refinishing. Technician B says ASE offers a certification test for Damage Analysis and Estimating. Who is right?
   (A) A only.
   (B) B only.
   (C) Both A and B.
   (D) Neither A nor B.
2. Technician A says that ASE certifies collision repair technicians through a voluntary testing program. Technician B says NATEF develops the standards for automotive repair programs. Who is right?
   (A) A only.
   (B) B only.
   (C) Both A and B.
   (D) Neither A nor B.
3. Each of the following is a benefit of ASE certification EXCEPT:
   (A) help a technician land a job.
   (B) help the collision repair shop attract customers.
   (C) certified technicians are certified for life.
   (D) demonstrate competency in specific areas.
4. Each ASE certification test lasts ______ hours.
   (A) one to two
   (B) three
   (C) five
   (D) more than five
5. All questions on ASE certification tests are ______.
   (A) difficult
   (B) multiple choice
   (C) essay
   (D) fill-in-the-blank or incomplete sentence questions
6. Negative questions are commonly used in ASE certification tests. A negative question may contain all of the following words EXCEPT:
   (A) not.
   (B) least likely or most likely.
   (C) except.
   (D) ordinarily.

7. Technician A says that he must pass a test to become ASE certified. Technician B says that he must have two years of collision repair shop experience to become ASE certified. Who is right?
   (A) A only.
   (B) B only.
   (C) Both A and B.
   (D) Neither A nor B.
8. A technician who passes tests in Painting and Refinishing, Nonstructural Analysis and Damage Repair, Structural Analysis and Damage Repair, and Mechanical and Electrical Components is certified as an ASE ______ Collision Repair/ Refinishing Technician.
   (A) Expert
   (B) Master
   (C) Supervisor
   (D) Professional
9. Technician A says that it is a good idea to always read the question and answers carefully before selecting the best answer. Technician B says that if there is a question you cannot answer to skip it and come back to it later. Who is right?
   (A) A only.
   (B) B only.
   (C) Both A and B.
   (D) Neither A nor B.



Chapter 35

Employment Strategies

Objectives

After studying this chapter, you will be able to:

- Know what a job in a body shop is like.
- Understand the payment methods.
- Describe the job search process, including the interview.
- Understand how to keep a job.
- Know how to obtain training after finding a job.

Technical Terms

attitude
comeback
Inter-Industry Conference on Auto Collision Repair (I-CAR)
job shadowing
punctual
self-motivation
team
Tech-Cor
unemployment benefits

Introduction

This chapter explains how to find and keep a job. Most importantly, it discusses what to expect from a job in the collision repair field and explains how to put your skills to good use. This section starts with the most important question of the job search: What kind of career do you want? It will discuss the positives and negatives of a collision repair career while explaining what it is like to work in a body shop. This chapter will also detail how to look for a job, how to be successful in a job interview, and how to succeed in the workplace once you land that first job.

Determining Your Goals

It can be difficult to know what type of work you may want to do while still in school. It's important to know that there is more to a job than making money. True career satisfaction comes from doing a good job and feeling that the job is important. Some schools have ***job shadowing*** arrangements with industries. In this type of arrangement, the student spends time observing what goes on in a business, such as a body shop. This experience is invaluable. The student can actually see what types of tasks a collision technician performs. Explore as many careers as possible to find one that suits you.

Working as a Collision Repair Technician

Collision repair and refinishing can be a rewarding career choice. Each individual has a unique perspective on auto body repair. To some people, it is nothing more than difficult manual labor. Yes, body work is tough physical labor, but it also requires a high level of organization, skills, creativity, and even a sense of artistry. The job is mentally challenging because there will always be a new style of vehicle, new paint chemistries, and new repair procedures to learn. A good technician will constantly search for ways to perform tasks faster and better. Continuous improvement is the work philosophy of successful body repair technicians.

Some people view body repair as a dirty job. Body repair does produce dust, drive trains are oily, and refinishing can be messy. Some shops, **Figure 35-1**, minimize the amount of dirt by vacuuming and cleaning throughout the workday. Another criticism of collision repair is technicians are exposed to harmful chemicals on a daily basis. This is true, but the industry has long ago developed the procedures, tools, and technology to dramatically reduce exposure to chemical hazards.

Figure 35-1. *A by-product of collision repair is dirt and dust. Some shops minimize the amount of debris by vacuuming and cleaning throughout the workday.*

Body work is fast-paced. Successful technicians are organized and conscientious. Organization means planning ahead and keeping tools in an assigned spot. The best, most experienced technicians can work on two or three vehicles at the same time. While body filler is curing on one repair, for example, the technician welds a panel on a different vehicle. Working on multiple vehicles at the same time allows the organized professional to maximize productivity and income.

Perhaps the greatest reward in body repair is the satisfaction of knowing a job was done right. Few emotions can compare to the feeling of pride one gets when the repair is completed, the vehicle looks great, and the customer is satisfied.

Payment Method

There are four basic ways that a technician may be paid: hourly, salary, commission, and hourly plus bonus. Some shops may have a slightly different payment method, but the basic methods are described.

An hourly wage is used in many jobs. The technician is paid a specified amount for each hour worked. Hours worked beyond eight hours in one day of a forty-hour workweek are called overtime hours. Overtime hours may be paid at a higher hourly rate, usually 1.5 times the normal hourly rate. Hourly workers usually punch a time clock. **Figure 35-2** shows a time clock. The time clock records the time an employee arrives and leaves.

A variation of the hourly rate is called salary. In a salary arrangement, an individual is paid a certain amount of money each week, regardless of the number of hours worked. If the agreed on number of hours per week is 45 hours, then the individual is paid for that

ATTENTION
UNIFORMS WILL BE DELIVERED ON MONDAYS.
PLEASE BRING IN YOUR SOILED UNIFORMS EVERY MONDAY!!!!!!!
Thank you. Don
Metal Shop
Paint Shop
Office
Detail
Maintenance

Figure 35-2. *An hourly wage is used in many jobs. The technician is paid a specified amount for each hour worked. Hourly workers usually punch a time clock.*

many hours. If the employee happens to work 50 hours one week, there is no further compensation for the extra time worked.

Commission means the technician is paid a dollar amount based on each vehicle repaired. The dollar amount is based on the labor hours listed on the estimate. For example, the estimator decides a damaged vehicle will require 10 hours of body repair labor. The shop's labor rate is $40 per hour. A technician making 50% commission would be paid $200 for making the repair, 10 hours at $20 per hour. If the technician finishes the repair in less time, the payment is still $200. Also, if the repair takes longer, the payment still remains at $200. Refinish labor works the same way. An organized, fast-working technician can get paid for 80–100 commission hours of work in a 40-hour work week.

When sloppy work must be redone, called a ***comeback***, it is fixed for free. A commission worker must produce good work that will satisfy the customer. Comebacks and slow work habits will severely limit the technician's ability to make a decent wage. The number of vehicles awaiting repair can vary. There may be periods when there are three or four weeks of work waiting to be repaired and other periods when a customer's vehicle can be repaired the next day because there are no cars waiting. Working on commission during a slow period is difficult. If there is no work, there is no pay, even if the technician is at the shop and ready to work. A commission pool lumps labor produced by all of a shop's technicians together. Each technician is paid a percentage of the total.

Some shops pay the workers by the hour and track the labor output based on the estimated labor hours. A quota is established, such as 150% productivity. This means that if a technician produces 60 hours of labor in a 40-hour workweek, the 150% productive quota has been reached. The technician is paid a bonus for productivity. The bonus may be paid weekly, monthly, or yearly.

Benefits

Benefits may include employer paid health insurance, vacation, holidays, sick time, and retirement. Many small businesses, which include most body shops, are not able to offer benefits. Benefits, in addition to wages, should be considered when choosing a job. Paid health insurance means that the shop pays the premium on a health insurance policy for the employee and, in some cases, the employee's family. Some shops pay the entire premium, while other shops pay a portion of the premium. Some shops pay nothing at all. Health insurance is necessary, but it is expensive. Therefore, paid health insurance is a highly desirable benefit.

Paid holidays mean that the shop pays the worker for a day that he does not work. Usually the employee must work the day before and the day after the holiday to be paid for the holiday.

Paid vacation may be given after one year of service. Some shops shut down for one or two weeks during the summer. Other shops allow workers to schedule vacation when it suits them. Paid sick time means that if the worker must stay home because of illness, the worker will still be paid. Paid retirement means that the shop contributes additional money into an employee's retirement account.

When work is not available, or there isn't enough work for all employees, the shop may lay off employees. A lay off means that the technician does not report for work until the employer calls him back. Laid off technicians may look for another job. The technician is not paid during this time but may be eligible for ***unemployment benefits.*** These benefits are available to technicians who lost their jobs due to lack of work. Unemployment benefits are funded by the employer as well as state and federal programs.

When choosing a job, both wages and benefits should be taken into account before you make a decision.

Job Hunting

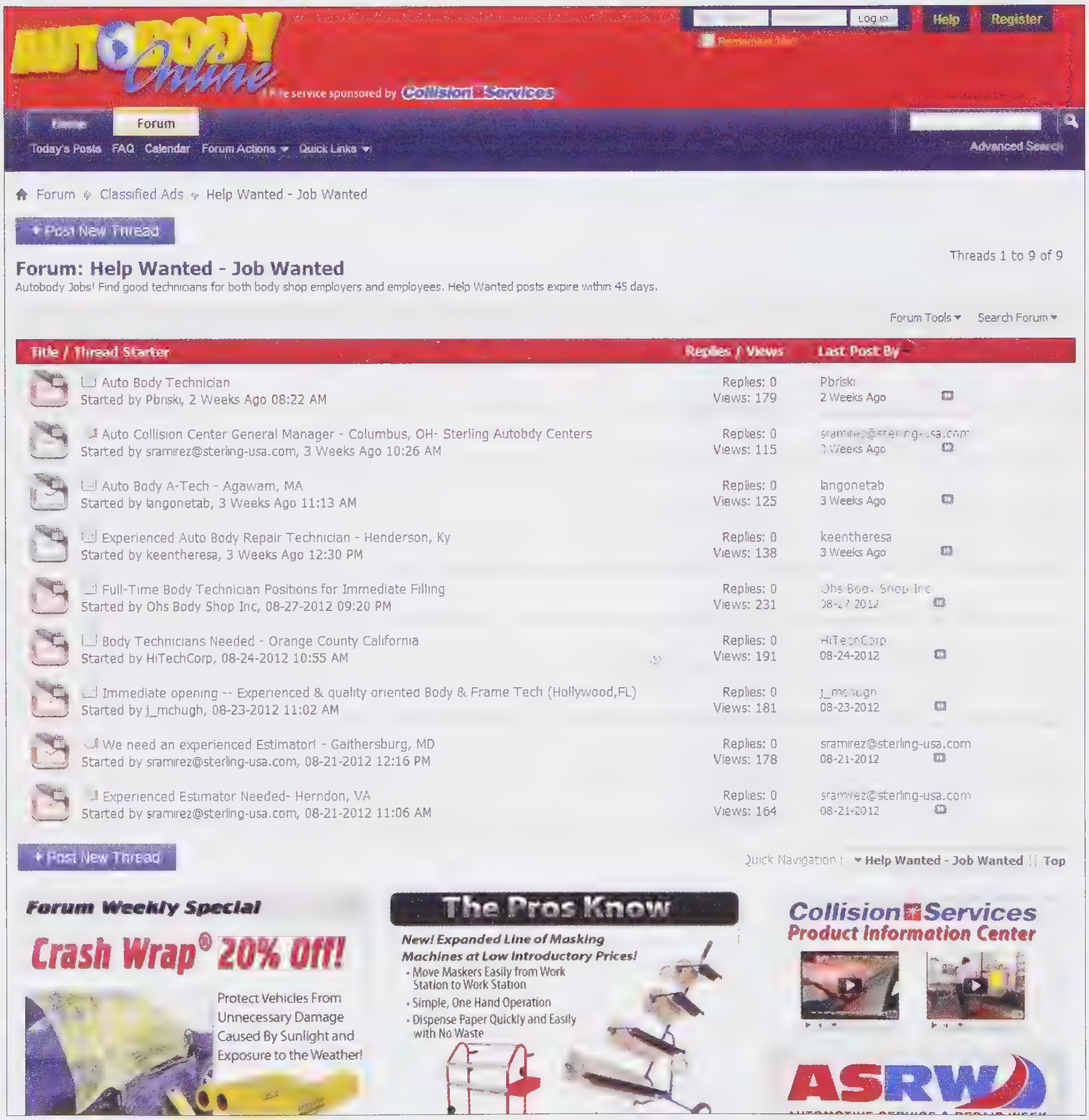
This section explains some methods used to look for a job. The search for employment is not easy. The search is often frustrating and may take more time and effort than you ever imagined. A successful job hunt requires focus and determination.

Job openings can sometimes be found in the newspaper. A newspaper "Help Wanted" ad notifies the reader of a job opening. The ad will contain the company's contact information. It may also tell you the wages to be paid and the required minimum qualifications.

The Internet is also a good place to look for employment. Many job boards and search sites offer job search tutorials. See **Figure 35-3.** These sites are also very helpful when it comes to crafting a résumé.

Many job openings are not advertised. In the referral method of job hunting, someone knows about a shop looking for technicians and tells the interested person. Body repair instructors are a good source for referrals.

In the visitation method of job hunting, you visit collision repair shops to see if they are hiring. Leave a résumé with the shop manager even if the shop is not hiring. The résumé may still get you a job later. If you have targeted a specific body repair shop, and are determined to get a job there, it may take several visits and multiple conversations with the owner before you get hired.



Forum: Help Wanted - Job Wanted

Autobody Jobs! Find good technicians for both body shop employers and employees. Help Wanted posts expire within 45 days.

Threads 1 to 9 of 9

Title / Thread Starter	Replies / Views	Last Post By
Auto Body Technician Started by Pbriski, 2 Weeks Ago 08:22 AM	Replies: 0 Views: 179	Pbriski 2 Weeks Ago
Auto Collision Center General Manager - Columbus, OH- Sterling Autobdy Centers Started by sramirez@sterling-usa.com, 3 Weeks Ago 10:26 AM	Replies: 0 Views: 115	sramirez@sterling-usa.com 3 Weeks Ago
Auto Body A-Tech - Agawam, MA Started by langonetab, 3 Weeks Ago 11:13 AM	Replies: 0 Views: 125	langonetab 3 Weeks Ago
Experienced Auto Body Repair Technician - Henderson, Ky Started by keentheresa, 3 Weeks Ago 12:30 PM	Replies: 0 Views: 138	keentheresa 3 Weeks Ago
Full-Time Body Technician Positions for Immediate Filling Started by Ohs Body Shop Inc, 08-27-2012 09:20 PM	Replies: 0 Views: 231	Ohs Body Shop Inc 08-27-2012
Body Technicians Needed - Orange County California Started by HiTechCorp, 08-24-2012 10:55 AM	Replies: 0 Views: 191	HiTechCorp 08-24-2012
Immediate opening -- Experienced & quality oriented Body & Frame Tech (Hollywood,FL) Started by j_mchugh, 08-23-2012 11:02 AM	Replies: 0 Views: 181	j_mchugh 08-23-2012
We need an experienced Estimator! - Gaithersburg, MD Started by sramirez@sterling-usa.com, 08-21-2012 12:16 PM	Replies: 0 Views: 178	sramirez@sterling-usa.com 08-21-2012
Experienced Estimator Needed- Herndon, VA Started by sramirez@sterling-usa.com, 08-21-2012 11:06 AM	Replies: 0 Views: 164	sramirez@sterling-usa.com 08-21-2012

Forum Weekly Special
Crash Wrap® 20% Off!
Protect Vehicles From Unnecessary Damage Caused By Sunlight and Exposure to the Weather!

The Pros Know
New! Expanded Line of Masking Machines at Low Introductory Prices!
- Move Maskers Easily from Work Station to Work Station
- Simple, One Hand Operation
- Dispense Paper Quickly and Easily with No Waste

Collision Services
Product Information Center
ASRW

Figure 35-3. *Today, the Internet has eclipsed the newspaper as the preferred place to search for a job. Many job boards and search sites offer job search tutorials.*

The Job Interview

The interview gives you the opportunity to learn more about the shop, and to convince the employer that you are the best person for the position. The employer wants to know if you have the skills needed for the job. Adequate preparation is essential for making a lasting, positive impression. The first step is to research the employer and the job. Know the mission of the employer and specifics about the job. Also, try to learn what the shop looks for when hiring new employees.

Be prepared to answer questions. Generate a list of questions a prospective employer is most likely to ask. Internet job sites often have lists of questions employers tend to ask. Practice answering the questions. Have a friend or family member interview you, or practice by yourself in front of a mirror until you are happy with your responses. Also, have a list of questions you want answered. For example, do you want to know if the shop offers on-the-job training? Perhaps you would like to know about opportunities for advancement.

Create a list of everything you will take to the interview and set them out the night before the interview. This seems simple enough. However, if you wait to grab items at the last minute, you will likely forget something important. Another obvious, but no less important step is to know exactly where to go for the interview. Being late for an interview is a deal killer. Verify the address of the interview location by checking the site beforehand, if possible. Plan to arrive ready for the interview at least 10 minutes early. Finally, dress appropriately. "Work clothing" is suitable for an interview at a collision repair shop.

Prior preparation will make you feel more confident and comfortable during the interview. During the interview process, be polite, friendly, and cheerful. Use a firm handshake. Maintain eye contact at all times. Answer all questions carefully and as completely as you can. Be honest about your abilities. Avoid chewing gum and fidgeting. Also, be aware of questions you legally do not have to answer, such as those related to age, marital status, religion, or family background.

A prospective employer may ask you to take employee tests. Some employers administer tests to job candidates to measure their knowledge or skill level under stress. Since all employers support a drug-free workplace, most will likely require you to take a drug test, if hired.

After the interview, send a letter to the employer within 24 hours, thanking him or her for the interview. If you get a job offer, respond to it quickly. If you do not receive an offer after several interviews, evaluate your interview techniques and seek ways to improve them.

Evaluating Job Offers

If the owner offers you the job, consider if the job is something that you want to do. Will the job provide good experience and professional growth? Are the pay and benefits adequate? When considering a job offer or comparing two or more positions, you should explore the following work factors:

- Physical surroundings—Where is your workspace located? Is the atmosphere conducive to your style of working? Is parking provided? Is public transportation close by?
- Work schedule—Will the workdays and work hours mesh with your lifestyle? Is occasional overtime work required?
- Income and benefits—Is the proposed wage fair? Will you receive benefits that are just as valuable as extra income? How much sick leave is granted during the year? Is personal or emergency leave available? What is the vacation leave policy?
- Job obligations—Will you be expected to join a union or other professional organization? If so, what are the costs?
- Advancement potential—Is there opportunity for advancement? After demonstrating good performance, how soon can you seek a position with more responsibilities? Are training programs provided?

Talking about advancement requires considerable diplomacy. After all, you should not appear too eager to leave the job for which you are interviewing. Many employers would expect a new employee to remain at least one year at that job. If you place undue emphasis on getting some other job, you will appear uninterested in the current opening.

You may also want to explore the transportation options to and from work. Can you get to work in reasonable time by taking public transportation? Are carpools available? How much effort it takes to get to work will greatly affect your satisfaction with the job.

Succeeding in the Workplace

After securing employment, adjusting to your new duties and responsibilities will occupy your first few weeks. Your supervisor and coworkers will help you learn the routine. An introduction to company policies and procedures, as well as the special safety rules that all employees must know, is common for new employees.

While your coworkers will be watching what you do, they will also pay attention to "how you work." How to behave in the workplace is an important lesson all employees should learn. Making an effort to do your best will help you succeed.

Once you have a job, you must develop a strategy on how to remain employed. One of the best ways to remain employable and in-demand is to continue developing your skills.

Skill is the ability to do the job correctly; this ability is developed gradually. Experience, the desire to improve, and instruction will help build skill. Continue developing your skills for the job. Every technician is expected to be skilled and productive. As mentioned repeatedly in previous chapters, productivity is the goal of body repair. An organized and skilled worker will be productive. The more you produce, the more you earn.

Punctuality/Attendance

Employers want employees who are punctual, dependable, and responsible. They want their employees to be capable of taking initiative and working independently. Other desirable employee qualities include organization, accuracy, and efficiency.

A ***punctual*** employee is always prompt and on time. This means not only when the workday starts, but also when returning from breaks and lunches.

Being on time is important. Production schedules are set up with the assumption that every worker will be present. A tardy or absent worker will throw off the production schedule. Some workers are habitually late. Habitual lateness shows a lack of respect for the shop's rules and demonstrates poor time management skills. Owners, managers, and co-workers will resent a technician who cannot get to work on time or routinely misses work. Most shops will fire a technician with this type of problem.

Being dependable means that people can rely on you to fulfill your word and meet your deadlines. If you are not well, be sure to call in and let the employer know right away. If there are reasons you cannot be at work, discuss them with your employer and work out an alternate arrangement. Many people have lost jobs by not checking with their supervisor about time off.

Taking initiative means that you start activities on your own without being told. When you finish one task, you do not wait to hear what to do next. Individuals who take initiative need much less supervision. They have ***self-motivation***, or an inner urge to perform well. Generally, this motivation will drive them to set and accomplish goals. All of these qualities, when taken together, show that you are capable of working independently.

Attitude

Your attitude can often determine the success you have on your job. Your ***attitude*** is your outlook on life. It is reflected by how you react to the events and people around you. A smile and courteous behavior can make customers and fellow employees feel good about themselves and you. Clients and customers prefer to do business in friendly environments. Being friendly may take some effort on your part, but it does pay off.

The worker's attitude will also determine if the job is satisfying or not. A worker who feels exploited—not paid enough, worked too hard, or the recipient of all the undesirable assignments—will have a poor attitude. In contrast, a worker who feels fortunate to have the job, and thinks the job is satisfying, will have a good attitude. Attitude is the individual's choice. Two workers can be in the same situation and have opposite views of what is going on. If the job isn't satisfying, you may be best served to look for another job.

Productivity

There are many distractions in a body shop: co-workers, customers, loud shop noises such as those made by pneumatic air tools. Staying on task and completing a job is a sign of maturity. Staying on task means ignoring all of those distractions while working on a repair. Some unproductive technicians are easily distracted and cannot keep their minds focused on the task at hand. A technician is expected to be productive, and productivity can be measured using flat rate hours. In some shops, the minimum productivity to stay employed is 125%. If a technician cannot produce at least 125%—50 hours of labor in a 40-hour workweek—the technician will be fired!

One productivity killing behavior is socializing. A technician who spends time talking to co-workers rather than working will not be productive. All technicians will encounter unexpected problems that will take additional time to repair, but socializing is the most common reason for low productivity.

Always care for and maintain your tools. A clean and well-organized assortment of tools sends a message of professionalism. Collision repair technicians are expected to have their own set of tools. A good selection of well cared for and properly functioning tools is also an excellent way to be productive. Oiling your air-powered tools daily is an example. Failure to do so will quickly ruin your tools and greatly reduce your ability to do the job. Routinely acquiring new tools designed to make a repair quicker and easier is an excellent way to boost a technician's productivity.

Teamwork

Employers seek employees who can effectively serve as good team members. Due to the nature of most work today, teamwork is necessary. A ***team*** is a small group of people working together for a common purpose. Often teamwork requires flexibility and willingness to try new ways to get things done.

Other workers in the body shop can be of great benefit. They may be willing to show how to make a repair easier and faster. Getting along well with co-workers is important for job satisfaction. Many repairs require working side-by-side with two or more technicians. Negative attitudes in co-workers are infectious. Avoid the co-worker who has a negative attitude.

Technicians should recognize that the customer is also a part of the team, and it is the satisfied customer that keeps the shop in business. *Always* treat customers with respect and listen to what they have to say.

Honesty

Technicians are under a great deal of pressure to be productive. Often this pressure leads to errors of judgment, which can result in mistakes. If there is a problem, report it to the manager as soon as possible. If you make a mistake and cause damage, inform the manager. Do not try to cover it up. It may be discovered after the vehicle has left the shop and cause a bigger problem later on.

Continuing Education

Vehicles are constantly changing. To stay productive, technicians must continually learn and improve. This section lists some sources of continuing education.

The ***Inter-industry Conference on Auto Collision Repair (I-CAR)*** is an organization that trains auto body technicians. Classes are held at night or weekends. I-CAR classes are an excellent source of collision repair information. I-CAR can be contacted at 1-800-ICARUSA or www.I-CAR.com.

Tech-Cor is an organization that researches collision repair methods to set standards and guidelines for the industry. The information available is vehicle model specific and thoroughly detailed. The procedures explained have been tested in a shop environment. The information can be viewed at www.techcor.com.

Companies that make collision repair products, such as body filler, plastic repair material, and paint, often hold product seminars and training classes. These classes can be a good source of information. The training classes may be held in a shop or at the company's training facility. Thorough knowledge about a product will make a technician more productive. Contact the supply jobber to see if a seminar is offered.

Equipment manufacturers often train technicians on the proper use of their products. As with product seminars, the training can be at the shop or at a central training site. If a shop buys a frame machine, for example, the manufacturer will usually offer some type of training.

Employees of dealerships may be allowed to attend OEM training in collision repair. For example, an employee of a Toyota dealership can attend company sponsored training sessions to learn the factory recommended way to repair collision-damaged Toyota products.

Trade magazines always contain articles on repair technique. These magazines are usually sent to a collision repair shop at no charge. Reading the articles each month will help technicians develop new skills, as well as introduce them to industry news and new products designed to boost productivity. Trade magazines are an excellent resource as are annual trade shows such as NACE (International Autobody Congress and Exposition) and SEMA (Specialty Equipment Marketing Association). Trade shows provide attendees with educational seminars, product demonstrations, and special events, as well as networking opportunities.

An Internet class offers the technician training that can suit his own particular schedule. The Internet is a virtual tradeshow and is rapidly evolving to be an incredible source of product information and skill-building opportunities.

Summary

- Find out what type of career you want.
- Collision repair technicians may be paid hourly, by commission, or by hourly/bonus.
- All technicians must be productive.
- At some shops the minimum productivity to stay employed is 125%.
- Benefits vary according to the individual shop.
- Technicians are expected to own a collection of job-specific tools.
- Bodywork is fast paced. Successful technicians are organized.
- Hiring practices vary; each shop is different.
- Stay on task. Complete every project that is given to you.
- Make good use of continuing education opportunities.

Review Questions

Please do not write in this textbook. Place your answers on a separate sheet of paper.

1. When an unsatisfied customer brings a vehicle back for rework because the job wasn't done right the first time it's called a ______.
2. The goal of all body shops is to make ______.
3. Why should a student job shadow in a body shop?
4. In ______ payment, the technician is paid a percentage of the labor on the estimate regardless of how long it takes to complete the work.
5. Overtime is paid after eight hours in one day of a forty-hour workweek. True or False?
6. Explain how a technician is paid in a commission pool.
7. A technician is expected to be productive. ______ is productivity-killing behavior.
8. ______ include health insurance, paid vacation, and paid holidays.
9. Collision repair technicians are expected to have their own set of tools. Most technicians continually buy tools to improve their productivity. True or False?
10. Technicians work on only one vehicle at a time. True or False?
11. A technician should ignore the customer's questions. True or False?
12. You should leave a résumé with potential employers even if no positions are currently available. True or False?

ASE-Style Questions

1. At minimum, a technician should be ______.
   (A) 50% productive
   (B) 75% productive
   (C) 100% productive
   (D) 125% productive
2. A commission pool lumps labor produced by all of a shop's technicians together. Each technician is then paid a ______ of the total.
   (A) percentage
   (B) even split
   (C) half
   (D) comeback
3. Technician A says that body shops typically provide technicians with all the necessary "tools of the trade." Technician B says technicians are required to have their own tools. Who is right?
   (A) A only.
   (B) B only.
   (C) Both A and B.
   (D) Neither A nor B.
4. Which of the following is a way to find a job?
   (A) Newspaper/Internet advertisement.
   (B) Referral.
   (C) Visitation.
   (D) All of the above.
5. Which of the following is a source of continuing education?
   (A) Equipment training.
   (B) Product seminars.
   (C) I-CAR.
   (D) All of the above.
6. Technician A says that punctuality and attendance are important. He also says that a tardy or absent worker will throw off the production schedule. Technician B says that staying on task and finishing what you started are important. Who is right?
   (A) A only.
   (B) B only.
   (C) Both A and B.
   (D) Neither A nor B.
7. Which of the following is a factor that may take a technician off task?
   (A) Co-workers.
   (B) Customers.
   (C) Radio music.
   (D) All of the above.
8. You are working on a vehicle and accidentally break the antenna. You should ______.
   (A) pretend that it did not happen
   (B) say that it was that way when it came into the shop
   (C) tell the manager immediately
   (D) put it back together quickly so no one notices
9. Continuing education is a great way to increase productivity. The following are good sources for continuing education EXCEPT:
   (A) I-CAR.
   (B) Tech-Cor.
   (C) commission pool.
   (D) product seminars.

Appendix

SAE Standard/Foot-Pounds						
Grade of Bolt	**SAE 1 & 2**	**SAE 5**	**SAE 6**	**SAE 8**		
Min. Ten. Strength	64,000 P.S.I.	105,000 P.S.I.	133,000 P.S.I.	150,000 P.S.I.		
Markings on Head	⬢	⬢	⬢	⬢	Size of Socket or Wrench Opening	
U.S. Standard	Foot Pounds				U.S. Regular (in.)	
Bolt Dia. (in.)					Bolt Head	Nut
1/4	5	7	10	10.5	3/8	7/16
5/16	9	14	19	22	1/2	9/16
3/8	15	25	34	37	9/16	5/8
7/16	24	40	55	60	5/8	3/4
1/2	37	60	85	92	3/4	13/16
9/16	53	88	120	132	7/8	7/8
5/8	74	120	167	180	15/16	1
3/4	120	200	280	296	1-1/8	1-1/8

Metric Standard						
Grade of Bolt		**5D**	**.8G**	**10K**	**12K**	
Min. Ten. Strength		71,160 P.S.I.	113,800 P.S.I.	142,200 P.S.I.	170,679 P.S.I.	
Markings on Head		5D	.8G	10K	12K	Size of Socket or Wrench Opening
Metric		Foot Pounds				Metric
Bolt Dia.	U.S. Dec. Equiv.					Bolt Head
6mm	.2362	5	6	8	10	10mm
8mm	.3150	10	16	22	27	14mm
10mm	.3937	19	31	40	49	17mm
12mm	.4720	34	54	70	86	19mm
14mm	.5512	55	89	117	137	22mm
16mm	.6299	83	132	175	208	24mm
18mm	.7090	111	182	236	283	27mm
22mm	.8661	182	284	394	464	32mm

Drill Sizes for Machine Screw Threads (75% Depth of Thread)

A bolt inserted in an ordinary nut, which has only one-half of a full depth of thread, will break before stripping the thread. Also a full depth of thread, while very difficult to obtain, is only about 5% stronger than a 75% depth.

These tables give the exact size of the hole expressed in decimals, that will produce a 75% depth of thread, and also the nearest regular stock drill to this size. Holes produced by these drills are considered close enough for any commercial tapping.

$$\text{Diameter of Tap, Minus } \frac{.974}{\text{No. threads per inch}} = \text{Diameter of Hole}$$

Tap Size	Threads per Inch	Diameter Hole (in.)	Drill	Tap Size	Threads per Inch	Diameter Hole (in.)	Drill
0	80	.048	3/64	10	32	.160	21
1	72	.060	53	10	30	.158	22
1	64	.058	53	10	28	.155	23
2	64	.071	50	10	24	.149	25
2	56	.069	50	12	28	.181	14
3	56	.082	45	12	24	.175	16
3	48	.079	47	14	24	.201	7
4	48	.092	42	14	20	.193	10
4	40	.088	43	16	22	.224	2
4	36	.085	44	16	20	.219	7/32
5	44	.103	37	16	18	.214	3
5	40	.101	38	18	20	.245	D
5	36	.098	40	18	18	.240	B
6	40	.114	33	20	20	.271	I
6	36	.111	34	20	18	.266	17/64
6	32	.108	36	22	18	.292	L
7	36	.124	1/8	22	16	.285	9/32
7	32	.121	31	24	18	.318	O
7	30	.119	31	24	16	.311	5/16
8	36	.137	29	26	16	.337	R
8	32	.134	29	26	14	.328	21/64
8	30	.132	30	28	16	.363	23/64
9	32	.147	26	28	14	.354	T
9	30	.145	27	30	16	.389	25/64
9	24	.136	29	30	14	.380	V

Tap Drill Sizes for Fractional Size Threads (75% Depth of Thread)

Tap Size	Threads per Inch	Diameter Hole (in.)	Drill	Tap Size	Threads per Inch	Diameter Hole (in.)	Drill
1/16	72	.049	3/64	1/2	20	.451	29/64
1/16	64	.047	3/64	1/2	13	.425	27/64
1/16	60	.046	56	1/2	12	.419	27/64
5/64	72	.065	52	9/16	27	.526	17/32
5/64	64	.063	1/16	9/16	18	.508	33/64
5/64	60	.062	1/16	9/16	12	.481	31/64
5/64	56	.061	53	5/8	27	.589	19/32
3/32	60	.077	5/64	5/8	18	.571	37/64
3/32	56	.076	48	5/8	12	.544	35/64
3/32	50	.074	49	5/8	11	.536	17/32
3/32	48	.073	49	11/16	16	.627	5/8
7/64	56	.092	42	11/16	11	.599	19/32
7/64	50	.090	43	3/4	27	.714	23/32
7/64	48	.089	43	3/4	16	.689	11/16
1/8	48	.105	36	3/4	12	.669	43/64
1/8	40	.101	38	3/4	10	.653	21/32
1/8	36	.098	40	13/16	12	.731	47/64
1/8	32	.095	3/32	13/16	10	.715	23/32
9/64	40	.116	32	7/8	27	.839	27/32
9/64	36	.114	33	7/8	18	.821	53/64
9/64	32	.110	35	7/8	14	.805	13/16
5/32	40	.132	30	7/8	12	.794	51/64
5/32	36	.129	30	7/8	9	.767	49/64
5/32	32	.126	1/8	15/16	12	.856	55/64
11/64	36	.145	27	15/16	9	.829	53/64
11/64	32	.141	9/64	1	27	.964	31/32
3/16	36	.161	20	1	14	.930	15/16
3/16	32	.157	22	1	12	.919	59/64
3/16	40	.155	23	1	8	.878	7/8
3/16	24	.147	26	1 1/16	8	.941	15/16
13/64	32	.173	17	1 1/8	12	1.044	1 3/64
13/64	30	.171	11/64	1 1/8	7	.986	63/64
13/64	24	.163	20	1 3/16	7	1.048	1 3/64
7/32	32	.188	12	1 1/4	12	1.169	1 11/64
7/32	28	.184	13	1 1/4	7	1.111	1 7/64
7/32	24	.178	16	1 5/16	7	1.173	1 11/64
15/64	32	.204	6	1 3/8	12	1.294	1 19/64
15/64	28	.200	8	1 3/8	6	1.213	1 7/32
15/64	24	.194	10	1 1/2	12	1.419	1 27/64
1/4	32	.220	7/32	1 1/2	6	1.338	1 11/32
1/4	28	.215	3	1 5/8	5 1/2	1.448	1 29/64
1/4	27	.214	3	1 3/4	5	1.555	1 9/16
1/4	24	.209	4	1 7/8	5	1.680	1 11/16
1/4	20	.201	7	2	4 1/2	1.783	1 25/32
5/16	32	.282	9/32	2 1/8	4 1/2	1.909	1 29/32
5/16	27	.276	J	2 1/4	4 1/2	2.034	2 1/32
5/16	24	.272	I	2 3/8	4	2.131	2 1/8
5/16	20	.264	17/64	2 1/2	4	2.256	2 1/4
5/16	18	.258	F	2 5/8	4	2.381	2 3/8
3/8	27	.339	R	2 3/4	4	2.506	2 1/2
3/8	24	.334	Q	2 7/8	3 1/2	2.597	2 19/32
3/8	20	.326	21/64	3	3 1/2	2.722	2 23/32
3/8	16	.314	5/16	3 1/8	3 1/2	2.847	2 27/32
7/16	27	.401	Y	3 1/4	3 1/2	2.972	2 31/32
7/16	24	.397	X	3 3/8	3 1/4	3.075	3 1/16
7/16	20	.389	25/64	3 1/2	3 1/4	3.200	3 3/16
7/16	14	.368	U	3 5/8	3 1/4	3.325	3 5/16
1/2	27	.464	15/32	3 3/4	3	3.425	3 7/16
1/2	24	.460	29/64	4	3	3.675	3 11/16

Metric Tap Drill Size

Metric Tap Drill Size

Metric Tap Size	Recommended Metric Drill				Closest Recommended Inch Drill			
	Drill Size (mm)	Inch Equivalent	Probable Hole Size (in.)	Probable Percent of Thread	Drill Size (mm)	Inch Equivalent	Probable Hole Size (in.)	Probable Percent of Thread
M1.6 × .35	1.25	.0492	.0507	69	—	—	—	—
M1.8 × .35	1.45	.0571	.0586	69	—	—	—	—
M2 × .4	1.60	.0630	.0647	69	#52	.0635	.0652	66
M2.2 × .45	1.75	.0689	.0706	70	—	—	—	—
M2.5 × .45	2.05	.0807	.0826	69	#46	.0810	.0829	67
*M3 × .5	2.50	.0984	.1007	68	#40	.0980	.1003	70
M3.5 × .6	2.90	.1142	.1168	68	#33	.1130	.1156	72
*M4 × .7	3.30	.1299	.1328	69	#30	.1285	.1314	73
M4.5 × .75	3.70	.1457	.1489	74	#26	.1470	.1502	70
*M5 × .8	4.20	.1654	.1686	69	#19	.1660	.1692	68
*M6 × 1	5.00	.1968	.2006	70	#9	.1960	.1998	71
M7 × 1	6.00	.2362	.2400	70	15/64	.2344	.2382	73
*M8 × 1.25	6.70	.2638	.2679	74	17/64	.2656	.2697	71
M8 × 1	7.00	.2756	.2797	69	J	.2770	.2811	66
*M10 × 1.5	8.50	.3346	.3390	71	Q	.3320	.3364	75
M10 × 1.25	8.70	.3425	.3471	73	11/32	.3438	.3483	71
*M12 × 1.75	10.20	.4016	.4063	74	Y	.4040	.4087	71
M12 × 1.25	10.80	.4252	.4299	67	27/64	.4219	.4266	72
M14 × 2	12.00	.4724	.4772	72	15/32	.4688	.4736	76
M14 × 1.5	12.50	.4921	.4969	71	—	—	—	—
*M16 × 2	14.00	.5512	.5561	72	35/64	.5469	.5518	76
M16 × 1.5	14.50	.5709	.5758	71	—	—	—	—
M18 × 2.5	15.50	.6102	.6152	73	39/64	.6094	.6144	74
M18 × 1.5	16.50	.6496	.6546	70	—	—	—	—
*M20 × 2.5	17.50	.6890	.6942	73	11/16	.6875	.6925	74
M20 × 1.5	18.50	.7283	.7335	70	—	—	—	—
M22 × 2.5	19.50	.7677	.7729	73	49/64	.7656	.7708	75
M22 × 1.5	20.50	.8071	.8123	70	—	—	—	—
*M24 × 3	21.00	.8268	.8327	73	53/64	.8281	.8340	72
M24 × 2	22.00	.8661	.8720	71	—	—	—	—
M27 × 3	24.00	.9449	.9511	73	15/16	.9375	.9435	78
M27 × 2	25.00	.9843	.9913	70	63/64	.9844	.9914	70
*M30 × 3.5	26.50	1.0433	Reaming Recommended to the Drill Size Shown					
M30 × 2	28.00	1.1024						
M33 × 3.5	29.50	1.1614						
M33 × 2	31.00	1.2205						
M36 × 4	32.00	1.2598						
M36 × 3	33.00	1.2992						
M39 × 4	35.00	1.3780						

Units of Measure

U.S. Customary	Metric
Length	
12 inches = 1 foot	1 kilometer = 1000 meters
36 inches = 1 yard	1 hectometer = 100 meters
3 feet = 1 yard	1 dekameter = 10 meters
5,280 feet = 1 mile	1 meter = 1 meter
16.5 feet = 1 rod	1 decimeter = 0.1 meter
320 rods = 1 mile	1 centimeter = 0.01 meter
6 feet = 1 fathom	1 millimeter = 0.001 meter
Weight	
27.34 grains = 1 dram	1 tonne = 1,000,000 grams
438 grains = 1 ounce	1 kilogram = 1000 grams
16 drams = 1 ounce	1 hectogram = 100 grams
16 ounces = 1 pound	1 dekagram = 10 grams
2000 pounds = 1 short ton	1 gram = 1 gram
2240 pounds = 1 long ton	1 decigram = 0.1 gram
25 pounds = 1 quarter	1 centigram = 0.01 gram
4 quarters = 1 cwt	1 milligram = 0.001 gram
Volume	
8 ounces = 1 cup	1 hectoliter = 100 liters
16 ounces = 1 pint	1 dekaliter = 10 liters
32 ounces = 1 quart	1 liter = 1 liter
2 cups = 1 pint	1 deciliter = 0.1 liter
2 pints = 1 quart	1 centiliter = 0.01 liter
4 quarts = 1 gallon	1 milliliter = 0.001 liter
8 pints = 1 gallon	1000 milliliters = 1 liter
Area	
144 sq. inches = 1 sq. foot	100 sq. millimeters = 1 sq. centimeter
9 sq. feet = 1 sq. yard	100 sq. centimeters = 1 sq. decimeter
43,560 sq. ft. = 160 sq. rods	100 sq. decimeters = 1 sq. meter
160 sq. rods = 1 acre	10,000 sq. meters = 1 hectare
640 acres = 1 sq. mile	

Temperature

Fahrenheit		Celsius
32° F	Water freezes	0° C
68° F	Reasonable room temperature	20° C
98.6° F	Normal body temperature	37° C
173° F	Alcohol boils	78.34° C
212° F	Water boils	100° C

Useful Conversions

When You Know:	Multiply by:	To Find:
Torque		
pound-inch	0.11298	newton-meters (N•m)
pound-foot	1.3558	newton-meters
Light		
foot candles	1.0764	lumens/meters^2 (lm/m^2)
Fuel Performance		
miles/gallon	0.4251	kilometers/liter (km/L)
speed		
miles/hour	1.6093	kilometers/hr (km/h)
Force		
kilogram	9.807	newtons (n)
ounce	0.278	newtons
pound	4.448	newtons
Power		
horsepower	0.746	kilowatts (kw)
Pressure or Stress		
inches of water	0.2491	kilopascals (kPa)
pounds/sq. in.	6.895	kilopascals
Energy or Work		
btu	1055.0	joules (J)
foot-pound	1.3558	joules
kilowatt-hour	3600000.0	joules

Conversion Table: Metric to U.S. Customary

When You Know:	Multiply By: * = Exact		To Find:
	Very accurate	Approximate	
Length			
millimeters	0.0393701	0.04	inches
centimeters	0.3937008	0.4	inches
meters	3.280840	3.3	feet
meters	1.093613	1.1	yards
kilometers	0.621371	0.6	miles
Weight			
grains	0.00228571	0.0023	ounces
grams	0.03527396	0.035	ounces
kilograms	2.204623	2.2	pounds
tonnes	1.1023113	1.1	short tons
Volume			
milliliters	0.20001	0.2	teaspoons
milliliters	0.06667	0.067	tablespoons
milliliters	0.03381402	0.03	fluid ounces
liters	61.02374	61.024	cubic inches
liters	2.113376	2.1	pints
liters	1.056688	1.06	quarts
liters	0.26417205	0.26	gallons
liters	0.03531467	0.035	cubic feet
cubic meters	61023.74	61023.7	cubic inches
cubic meters	35.31467	35.0	cubic feet
cubic meters	1.3079506	1.3	cubic yards
cubic meters	264.17205	264.0	gallons
Area			
square centimeters	0.1550003	0.16	square inches
square centimeters	0.00107639	0.001	square feet
square meters	10.76391	10.8	square feet
square meters	1.195990	1.2	square yards
square kilometers	0.386102	0.4	square miles
hectares	2.471054	2.5	acres
Temperature			
Celsius	*9/5 (then add 32)		Fahrenheit

Conversion Table: U.S. Customary to Metric

When You Know:	Multiply By: * = Exact		To Find:
	Very accurate	Approximate	
Length			
inches	*25.4		millimeters
inches	* 2.54		centimeters
feet	* 0.3048		meters
feet	*30.48		centimeters
yards	* 0.9144	0.9	meters
miles	* 1.609344	1.6	kilometers
Weight			
grains	15.43236	15.4	grams
ounces	*28.349523125	28.0	grams
ounces	* 0.028349523125	0.028	kilograms
pounds	* 0.45359237	0.45	kilograms
tons	* 0.90718474	0.9	tonnes
Volume			
teaspoons	* 4.97512	5.0	milliliters
tablespoons	*14.92537	15.0	milliliters
fluid ounces	29.57353	30.0	milliliters
cups	* 0.236588240	0.24	liters
pints	* 0.473176473	0.47	liters
quarts	* 0.946352946	0.95	liters
gallons	* 3.785411784	3.8	liters
cubic inches	* 0.016387064	0.02	liters
cubic feet	* 0.028316846592	0.03	cubic meters
cubic yards	* 0.764554857984	0.76	cubic meters
Area			
square inches	* 6.4516	6.5	square centimeters
square feet	* 0.09290304	0.09	square meters
square yards	* 0.83612736	0.8	square meters
square miles	* 2.589989	2.6	square kilometers
acres	* 0.40468564224	0.4	hectares
Temperature			
Fahrenheit	*5/9 (after subtracting 32)		Celsius

Fraction, Decimal, and Metric Equivalents

Inches		Millimeters	Inches		Millimeters
Fractions	Decimals		Fractions	Decimals	
	.00394	.1	15/32	.46875	11.9063
	.00787	.2		.47244	12.00
	.01181	.3	31/64	.484375	12.3031
1/64	.015625	.3969	1/2	.5000	12.70
	.01575	.4		.51181	13.00
	.01969	.5	33/64	.515625	13.0969
	.02362	.6	17/32	.53125	13.4938
	.02756	.7	35/64	.546875	13.8907
1/32	.03125	.7938		.55118	14.00
	.0315	.8	9/16	.5625	14.2875
	.03543	.9	37/64	.578125	14.6844
	.03937	1.00		.59055	15.00
3/64	.046875	1.1906	19/32	.59375	15.0813
1/16	.0625	1.5875	39/64	.609375	15.4782
5/64	.078125	1.9844	5/8	.625	15.875
	.07874	2.00		.62992	16.00
3/32	.09375	2.3813	41/64	.640625	16.2719
7/64	.109375	2.7781	21/32	.65625	16.6688
	.11811	3.00		.66929	17.00
1/8	.125	3.175	43/64	.671875	17.0657
9/64	.140625	3.5719	11/16	.6875	17.4625
5/32	.15625	3.9688	45/64	.703125	17.8594
	.15748	4.00		.70866	18.00
11/64	.171875	4.3656	23/32	.71875	18.2563
3/16	.1875	4.7625	47/64	.734375	18.6532
	.19685	5.00		.74803	19.00
13/64	.203125	5.1594	3/4	.7500	19.05
7/32	.21875	5.5563	49/64	.765625	19.4469
15/64	.234375	5.9531	25/32	.78125	19.8438
	.23622	6.00		.7874	20.00
1/4	.2500	6.35	51/64	.796875	20.2407
17/64	.265625	6.7469	13/16	.8125	20.6375
	.27559	7.00		.82677	21.00
9/32	.28125	7.1438	53/64	.828125	21.0344
19/64	.296875	7.5406	27/32	.84375	21.4313
5/16	.3125	7.9375	55/64	.859375	21.8282
	.31496	8.00		.86614	22.00
21/64	.328125	8.3344	7/8	.875	22.225
11/32	.34375	8.7313	57/64	.890625	22.6219
	.35433	9.00		.90551	23.00
23/64	.359375	9.1281	29/32	.90625	23.0188
3/8	.375	9.525	59/64	.921875	23.4157
25/64	.390625	9.9219	15/16	.9375	23.8125
	.3937	10.00		.94488	24.00
13/32	.40625	10.3188	61/64	.953125	24.2094
27/64	.421875	10.7156	31/32	.96875	24.6063
	.43307	11.00		.98425	25.00
7/16	.4375	11.1125	63/64	.984375	25.0032
29/64	.453125	11.5094	1	1.0000	25.4001

Acknowledgments

The author and the publisher would like to thank the following companies, organizations, and individuals for their contributions to Auto Collision Repair and Refinishing.

A and B Autobody Supply
A+ Autobody
Acura
Arnold's Body Shop
Art Senner
Bee Line, Co.
Bill Harrison
Brian Naslund
Carl Don Root
Carrie Hershberger
Chief Automotive Technologies
Chip Bradenburg
D's Paint and Body
Daimler AG
Dale Chisenhall
Daryl Porter
Dave Black
Dave Walsh
Dave's Autobody
Denny Boulton
DeVilbiss
Don Thomas
Donald Harr
Doug Johnson
Dupont
Ernie Parkinson
Ford Motor Company
Frank Hedrick
Frank's Automotive
Fred Badure
Gary Farris
Gates Corporation
General Motors Corporation
George Whitman
Green Chevrolet Body Shop
Gregg Whitmer
GretagMacbeth
Honda Motor Company
Jaguar
Jamie Thompson
Janine Crandell
Jason Clark
Jason Hedrick
Jeff Ford
Jim Curtis
Joe Hoskins
John Boghosian
John Perry
John S. Saia
John Wargo
Ken Olson
Kevin McGee
Kurt Lammon
Lakis Ford Body Shop
Larry Potts
Lincoln Electric
Mark Parks
Marty Hettle
Mike Hadsall
Mitchell International, Inc.
Mitsubishi Motors of North America
Morgan Manufacturing, Inc.
National Glass Association
National Institute for Automotive Service Excellence
Nicki Viager
Nissan
Patricia Willis
PPG Industries
Pro Spot International, Inc
Randy Dixon
Roberson's Used Auto Parts
Rod Abel
Route 150 Autobody
Roy Ven Horst
SATA USA
Scott Cunningham
Scott Mason
Sherwin Williams Co.
Steck Manufacturing Co., Inc.
Steve McMahon
Style-Line Corp.
Terrell Stringer
Thomas Boyd
Timothy Morgan
Tony Molla
Toyota Motor Sales, USA
Turks Autobody
Uftring Chevrolet Body Shop
Urethane Supply Company
Verlen Larsen
William J Johnston
William Strawn

Glossary

A

abrasive pad: Handheld pad used to scuff paint. The color of the pad indicates its level of abrasiveness.

accelerator: Chemical added to paint when a faster drying time, or cure time, is needed.

access window: A hole cut into the rail so a rod, hammer, or dolly can be inserted to work the buckle.

accumulator: Acts as a reservoir for the refrigerant and also removes moisture from the refrigerant in the system. Also known as a *receiver drier*.

acid rain: Rainwater with an acidic 5.6 ph. Acid rain will eat away a paint surface and cause pits.

active seat belts: Seat belts that must be buckled by the vehicle's occupants. There are two types of active seat belts: lap belts and shoulder belts, or shoulder harnesses.

active shaping: The deformation of a plastic part, such as a bumper, is actively worked out by the technician using a heat gun or heat lamp, and then shaped with the appropriate tool.

acute hazard: A hazard that causes an immediate (or within a few hours) reaction. A single exposure to an acute hazard can cause health problems.

additional charges: These charges are for services performed by the shop or a sublet company. Additional charges include disposal fees and sales tax.

additives: Used to give paint special capabilities or to prevent problems.

additive tinting: Tinting involves changing the color of refinish paint by adding or subtracting tints. In additive tinting, a specific tint or tints are added to the existing refinish paint.

adhesion: The stable joining of parts to one another.

adhesion promoter: Primer formulated to act as a bonding agent and hold refinish paint to existing paint.

adhesion solvent: The reducer component that chemically bites into the substrate. Once the paint is sprayed on a substrate and the adhesion solvent bites in, this solvent evaporates.

adhesives: Adhesives are used to bond certain replacement steel panels in place.

adjuster: See *insurance adjuster*.

agreement: See *direct repair agreement*.

aftermarket: The market for parts and accessories necessary for the upkeep or improvement of a previous purchase. This term is also used to refer to a part manufactured by an independent manufacturer rather than the one that made the original equipment part.

aftermarket parts: Parts manufactured by an independent manufacturer, not the one that made the OEM parts. As a rule, these parts cost less than OEM parts.

bumper cover: Bumpers may consist of an outer flexible bumper cover. The cover is also plastic and may be called a *fascia*.

aiming: Positioning the headlights with adjustable screws is called aiming. Aiming the headlights orients the lights straight ahead of the vehicle and at the proper height.

aiming screws: Adjustable screws used to properly position the headlight.

air bag module: Contains the folded air bag and the inflater substance.

air bag systems: Air bags are designed to inflate rapidly and absorb the forward, or lateral, energy of a vehicle's occupants during a collision.

air cap: Directs airflow from the air horns into the liquid paint coming out of the center orifice.

air change: The replacement of all the contaminated air in a confined area, such as a paint mixing room or paint storage room.

air chisel: A pneumatic tool used to make quick, rough cuts on sheet metal.

air conditioning system: Uses a refrigerant to absorb and remove heat from the passenger's compartment.

air file: A tool used to sand plastic body filler. There are two basic types of air files*:* straight-line air files and orbital air files.

air intake system: Brings cool outside air to the engine, At a minimum, the air intake system consists of plastic tubing and a plastic air cleaner box, as well as the intake plenum and manifold.

air makeup unit: As shop air is drawn into the spray booth, fresh replacement air is drawn into the shop from outside through a roof vent. In a colder climate, as heated shop air is replaced by cold outside air, the entire shop will rapidly cool. The solution is the air makeup unit, a device engineered to replace the heated air lost through exhaust.

air pressure control knob: Adjusts paint spray gun air pressure.

air punch/flanger: Device used to create a flange (a recessed lip) on sheet metal. Punch makes holes for rivets or plug welds.

air ratchet: A tool that uses pneumatic power to turn the socket drive.

air regulator: Used to adjust/set discharge air at the desired pressure.

air saw: An air powered hack saw.

alignment bar: Tool used to position panels during pulls.

alloy: A metallic substance that consists of one metal and at least one other alloying element. Alloying elements are materials added to metals to give them desired properties.

alternator: Produces electricity to recharge the battery and provide electricity to various vehicle systems when the engine is running.

aluminum: Aluminum is an alloy. It is strong and lightweight and is found throughout any vehicle.

ambient temperature: Surrounding air temperature.

anchoring: Used to prevent forward, rearward, sideways, and upward movement during full-frame repair.

anti-lock brake system: The ABS allows the driver to maintain control of the vehicle during panic stop situations.

appearance weld: A welded area that is visible.

apron: A single panel that connects the upper and lower frame rails.

arcing: A condition caused when a painter does not keep the spray gun at an equal distance from the panel during painting.

artistic masking: The creative use of masking tape to form a design or pattern. It entails two types: positive and negative. In positive, a color is sprayed and cured; masking tape is applied over the color to protect the color from overspray. In negative, the outline of a pattern is formed with masking tape and the paint is applied inside the border of the tape to make the design. It can be done following a drawn pencil design, a projected image, or freehand.

ASE: *See National Institute for Automotive Service Excellence.*

ASE certification: Awarded to a technician who passes an ASE test and has the required work experience.

ASE certification tests: The ASE offers four different tests to technicians in the collision repair industry with a fifth and separate test available for estimators wishing to receive ASE certification in damage analysis and estimating.

ASE collision repair technician: A technician who passes one or more of the ASE collision repair tests (B3, B4, B5) and meets the work experience requirements. Duties include repairing damaged bodies of cars and light trucks and repairing or replacing accessories, interior trim, glass, electrical parts, and plastic/composite parts.

ASE master collision repair/refinishing technician: An auto body technician that has successfully completed all four of the ASE Collision Repair and Refinishing Certification Tests (B2-B5) and meets the essential experience requirements is recognized with this title. The Damage Analysis and Estimating Certification Test (B6) is not required for this title.

ASE refinishing technician: A technician who passes the ASE painting and refinishing test (B2) and meets the work experience requirements. Duties include priming, sanding, and sealing, as well as successful paint application and finishing techniques.

assemblies: Major parts, which are made up of several smaller component parts, are referred to as assemblies.

asymmetrical: If measuring points are not the same distance from the centerline, they are said to be asymmetrical.

atom: The smallest particle of an element. An atom consists of protons, neutrons, and electrons.

atomization: The breaking up of liquid paint into tiny droplets.

atomized: When a volatile liquid is reduced to tiny particles or a fine spray.

attachment: An attachment, or hookup, connects the vehicle to the pull. The quickest and simplest attachments are hooks.

attitude: Refers to an individual's overall outlook on life. It is reflected by how one reacts to events and people. A positive and upbeat attitude is an individual's choice and can be beneficial on many levels, especially in the workplace.

auto-darkening helmet: An auto-darkening helmet eliminates welding mask visibility problems because the shade is clear until the arc is struck. The technician can see the work piece before beginning to weld. Once the arc is struck, the shade instantaneously becomes dark.

auto salvage yard: Buys wrecked vehicles and sells parts. Recycled vehicles go through a dismantling process. Usable, undamaged parts are removed from vehicles, inspected, tested, inventoried, and stored for resale.

automotive recycler: Auto recyclers purchase damaged, abandoned, or used vehicles from insurance companies or individuals, and sell the usable parts.

B

back blend: A technique used when hiding a slight mismatch between the refinish paint and the vehicle paint. A back blend is a stepping-in process; each coat covers slightly less area than the previous coat.

backer: A piece of plastic that is the same type of material as the damaged part. The backer should have the same shape as the repair and will help align the repair area.

back taping: A masking technique used to avoid the visible line problem–the ability to identify where the repair begins and ends.

baking: The process of using heat in the paint booth to accelerate the rate-of-cure of fresh paint.

ball joints: Ball-and-socket joints that allow suspension components to move up and down, and from side to side.

banana knife: A long-handled razor blade knife. The banana knife is used from inside the vehicle to cut through urethane adhesive.

banding: A painting technique used when spraying body panels that meet at a right angle.

bar hookup: This type of hookup can be used to make straight, side, upward, or downward pulls during full-frame repairs.

base centerline gauges: These gauges determine if damage is present in the center section of a vehicle.

basement full down-draft spray booth: Air enters through filters on the roof and exits through gratings in the floor. There are two channels in the floor, one on each side of the vehicle. Exhaust air draws overspray into and through these channels. One of two types of full down-draft spray booths.

basket-style: A style of pull that involves wrapping a chain around the frame and tying the chain to itself. A second chain is attached to the basket for pulling.

battery: The vehicle's source of electrical power.

bead: A deposit of filler metal from a single welding pass.

bed side: Pickup trucks have panels not found on cars. The bed side may be an outer skin, or it may include both inner and outer panels.

belts, pulleys: Engine components used to transfer motion from the engine's crankshaft to the power steering pump, air conditioner compressor, and alternator.

bench/rack system: A cross between a frame bench and a frame rack pulling system.

betterment: A term used by an insurance company when it will only pay for a part that is as good as, but not better than, the damaged part.

beveling: The use of an abrasive tool to produce a gradual slope.

binder: Thick resins that, when mixed with solvent, form a matrix to evenly disperse and contain the paint's pigment.

binding: A repair technique performed with an airless plastic welder. In binding, only the filler rod is melted; the base plastic is not heated.

bleeder valve: Valve used to purge air bubbles and excess brake fluid from a closed hydraulic brake system.

bleeding: The appearance of an undercoat pigment in the topcoat is called bleeding. The opposite of *hiding.*

blend: Painting technique used to hide a slight mismatch between the refinish paint and the vehicle paint.

blended panel: A panel partially sprayed with basecoat, but entirely sprayed with clearcoat.

blending: A method of paint application intended to hide slight color variation, or mismatch, between the repaired panel and the rest of the vehicle.

blind picking: Technique of using a body hammer on the backside of a damaged panel to bring up a low spot.

blind rivets: Non-threaded fasteners used to join metal together. Available in various sizes, they are permanent fasteners in that they cannot be removed and reused.

blistering: A paint defect caused by solvent or water trapped under dried paint film.

block sanding: A method of leveling out surface irregularities with a rubber sanding block and sandpaper.

blocking: Equipment used to prevent downward movement of structural parts during structural repairs and pulls.

blowgun: A handy tool that uses air pressure to remove dust and moisture from the vehicle.

blushing: A paint defect that makes the paint surface to look dull. Blushing is caused by moisture trapped in the paint film, and high humidity is the likely reason.

body chisel: Sharp cutting tool used to cut or separate sheet metal panels.

body fillers: A two-component putty that when mixed, hardens and can be sanded to the desired shape.

body hammers: A family of tools used to hammer damaged sheet metal back to its original contour.

body position: The ability of the painter to position and stretch their body to maintain a consistent distance and speed.

body shop estimates: Written account of what a collision repair will include and how much it will cost, in both materials and labor.

body style: The configuration of a vehicle's body panels. Examples of body styles are*:* sedan, coupe, station wagon, convertible.

body technician: A person that repairs the body of a damaged vehicle. The skills needed for this position include welding, panel alignment, plastic repair, and dent repair.

bonding: The use of adhesives to join replacements panels, both metal and plastic, to the vehicle.

bone: Tool used to break the seal between the glass and the gasket.

bound electrons: In some atoms, the electrons in the outer shell are tightly held and never leave the atom.

bows: Reinforcements designed to add rigidity to an automotive structure. For example*,* a roof is welded in place and has bows for reinforcement.

brazing: A process for joining similar or dissimilar metals using a filler metal. Brazing differs from welding in that brazing does not melt the base metals.

bridging: Occurs when improperly mixed surfacer is too thick to flow into and completely fill a scratch. The topcoat then sinks into the scratches making them visible. Can also refer to the unintended removal of paint when masking tape is pulled off.

buffing materials: Includes compounds, polishes, and glazes.

buffing window: The short span of time a fresh urethane clearcoat can still be buffed easily.

build: The thickness of paint film, measured in mils.

bull's eye: A paint defect, a visible ring around a painted and repaired area caused by poor surface preparation.

bull's-eye pick: A specialty body hammer designed to allow the picking (raising and smoothing) of low spots on sheet metal.

bumper assembly: A reinforced guard beam located at the front and rear of the vehicle. It is designed to protect the vehicle during minor impacts.

burns: Paint defect caused by improper buffing technique. Excessive heat concentrated in a small area can cause the paint to melt or burn.

bushings: Flexible, often rubber, components designed to allow the suspension to move without transmitting vibration and noise to the vehicle's frame or body.

butt joint: A welding joint where the width of the gap between panels is equal to the thickness of each panel.

butt joint with an insert: A joint where panels are aligned edge to edge with another panel. An insert is positioned below the joint to connect and reinforce the panels. Panels are plug welded to the insert and then the gap between the panels is stitch welded.

C

cab corner: Body part found on a pickup truck and located behind the door.

cable knife: A two-handled knife designed for windshield removal. Blade is inserted from outside the vehicle into the urethane holding a window in place.

camber: The inward or outward tilt of the tire when viewed from the front of the vehicle.

candy color: An aftermarket custom paint with a solid or metallic base and an intermediate coat of a tinted, semitransparent paint that will either make the base color more vivid or change the appearance of the base color. A candy color is brighter than a non-candy color.

carbon monoxide: A running engine produces carbon monoxide, a colorless, odorless gas that is extremely toxic.

cartridge-type respirator: The half-mask cartridge-type respirator is the most common type of respirator used for protection against organic vapors, dusts, mists, acid gases, and fumes. This respirator provides adequate protection only under limited conditions.

cast: A hue (color) can be influenced by adjacent hues. This subtle presence of an adjacent hue is called cast.

caster angle: The difference between the steering axis and true vertical.

catalyst: Anything that causes or accelerates a chemical reaction without itself being affected.

catalytic converter: Component of a vehicle's exhaust system designed to incinerate polluting exhaust gases.

caulking gun: A tool used to seal joints or seams, or to apply adhesives.

center link: In a parallelogram steering linkage, the center link is moved to the left or right by the pitman arm.

center pillar: The center pillar, or B pillar, which is found on four-door vehicles, is the body part onto which the front door latches and the rear door hinges are connected.

centerline gauge: Measuring tool used to check two-dimensional measurements during frame repair.

centerline: An imaginary plane that runs down the center of a vehicle, dividing the vehicle into left and right halves.

chain basket hookup: A frame pulling technique where the chain is looped around a cross member and tied to itself.

chain wrap hookup: A frame pulling technique where a chain is wrapped around the frame rail or cross member. This type of hookup can be used to make straight, angle, upward, downward, or side pulls.

chain-and-block tie-down: This type of tie-down is usually made on a frame rail at a cross member.

chalking: A condition where sun-damaged paint can be brushed off as a dry powder. It is caused by paint binder breakdown.

chasing the dent: A situation where attempts to repair a panel fail. Instead, more high spots and more work is created.

chemical adhesion: Occurs when one substance bonds to another through an interaction between atoms or molecules. For example, a basecoat bonds to a coat of sealer.

chemical paint stripper: A thick liquid product that when applied to a painted surface will soften and loosen any paint, making paint removal down to bare metal an easy task.

chemical resistance: The ability of a finish to withstand exposure to solvents such as gasoline.

chisel: A metal tool with a sharp beveled edge used to cut metal.

chroma: The intensity or brilliance of a hue (color).

chronic hazard: Anything that can cause long-term health damage, usually as the result of repeated or prolonged exposure to the hazard. An example is sanding dust.

circuit breaker: A device used to halt excessive current flow, but unlike a fuse or fusible link, it is not permanently damaged by high current flow.

claim: When an insured person suffers a loss and reports this loss to the insurance company.

claim center: A location (a claim center can be online) where the insured can go to and make an insurance claim.

claw hook: One of the three types of chain hooks used in collision repair. The claw hook attaches chains to other chains.

clockspring: A coil of wire that retracts and expands inside its housing as the steering wheel turns. It maintains the electrical connection between the driver-side air bag module and the wiring harness.

coated glass: Glass that has been treated with a light-blocking chemical film.

coil spring impact sensor: Rapid deceleration causes the sensor's roller to be thrown forward and uncoil. The roller touches electrical contacts, sending an electrical signal to the control module.

color sanding: Removal of surface defects prior to buffing. It is performed with very fine grits of sandpaper.

color wheel: An instrument used to plot color qualities such as hue and chroma. An aid to color matching.

color-corrected lightbulbs: Available for use in the spray booth, these bulbs produce light with a wavelength balance similar to natural light.

combination damage: A situation where two or more damage conditions are present in one vehicle.

combination pull: A combination of different pulls such as angle and downward pulls, or angle and upward pulls used to correct mash, sidesway, twist, sag, and kickup.

combination technicians: Perform all types of repairs on damaged vehicles, e.g., body, frame, mechanical, refinishing, and detailing.

come-along: A hand-operated ratcheting winch that uses strong cables to move heavy objects closer together.

comeback: When sloppy work must be redone.

comparative laser: A telescoping tube with a laser emitter at each end that compares an undamaged side of the vehicle with the damaged side.

comparison: A dimension taken from an undamaged vehicle of the same type, or an undamaged portion of the vehicle being repaired.

complete paint job: The entire vehicle is painted as compared to painting a single panel.

compound: The abrasive material used to cut away a very thin layer of paint and expose a smooth, unblemished surface.

compounding: Involves the use of an aggressive pad and a coarse abrasive (compound) to quickly remove paint defects such as sanding scratches.

comprehensive claim: Insurance that covers damages caused by something other than a collision.

comprehensive insurance: Insurance coverage that helps pay for losses due to fire, theft, or other losses that are not the result of a collision.

comprehensive tint system: A paint matching system that contains pigment, solvent, binder, and additives.

compressed air system: Supplies the shop with clean, dry compressed air. The compressed air system consists of an air compressor, air dryer, air piping, air regulators, and air hoses.

compressor: Changes the low-pressure refrigerant gas in the system into a high-pressure gas.

computer-aided measuring systems: Locate damage by comparing vehicle dimension standards stored in the computer against measurements taken from the vehicle.

condensate: The product of condensation.

condenser: Functions like a radiator to cool the refrigerant.

conductors: Materials made up primarily of atoms with free electrons, such as copper or aluminum, are called conductors because they conduct electricity.

cone: A measuring tool used to find the center of a round hole.

constant velocity joint: Found at each end of the drive axle, the CV joints transfer rotation through various angles without variation in drive axle speed even as the wheels turn or move up and down.

contact tube: Component that screws into the end of the MIG welding gun and establishes a good electrical connection between the gun and the welding wire.

continuous weld: An uninterrupted weld bead.

control arms: Pivoting suspension components that help maintain alignment of the wheel or axle assembly while permitting needed suspension travel.

control points: Holes located in the four corners of the vehicle's center section that will support the weight of the vehicle.

coolant: A fluid circulated through the cooling system that is engineered to absorb heat from the engine block.

cooling system: Manages heat produced by the engine.

counterpoint: One of two types of tie-downs, a counterpoint tie-down is positioned away from the damage and prevents vehicle movement.

coverage chart: A paper chart featuring black and white squares designed to help avoid hiding issues.

cowl: The cowl, or firewall, forms the front portion of the passenger's compartment.

cowl vent panel: A vent in the portion of the vehicle located just below the vehicle's windshield, specifically located between the engine firewall and the front of the dash panel.

cracking: Sun induced cracking begins as tiny slits in the paint surface. As the paint weathers, the slits will grow larger and the paint finish will begin to look dull.

cradle-to-grave: EPA regulations state that the collision repair shop is responsible for all hazardous wastes it generates. Cradle-to-grave means the shop is responsible for hazardous material from the time it enters the shop until the hazardous waste is properly disposed of.

crash beam: Part of the door assembly, the high-strength steel crash beam is hidden in the door and helps protect occupants in the event of a side impact.

creeper: A rolling device that allows a technician access to the underside of a vehicle.

cross camber: A comparison of the camber on the left and right sides of the vehicle.

cross caster: The sum of the left and right caster values.

cross-draft spray booth: A style of paint spray booth where air travels over the vehicle and is vented out the other end of the booth.

cross-linking: The chemical bond (link) formed between molecular chains.

cumulative formula: This type of paint formula lists the weight of the entire mixture as each tint is added to the paint. It lists the progressive weight as each tint is added to the formula.

curb weight: The weight of a vehicle without passengers or cargo, but with a full tank of gas, the engine full of oil, and the cooling system full of coolant.

cure: To harden. A process during which a chemical reaction results in a harder, more stable linkage such as that found in an adhesive bond.

custom painting: The application of a unique color or color pattern to a vehicle.

cut-off tool: A spinning disc comprised of abrasive materials that can grind and cut through metal panels.

cut-out knife: Two-handled knife used for glass removal. Also known as a *cable knife*.

cutting in: The act of pre-painting inaccessible areas of new replacement parts prior to installation. This is known as trimming, edging, or cutting in.

D

damage diagram: A sketch that shows where damage or misalignment is found on a vehicle. The diagram can be used to develop a repair plan.

damming tape: Product used to form a barrier intended to prevent urethane from squeezing out from under the glass.

datum: An imaginary plane underneath the vehicle. All height measurements are referenced to datum.

dealership body shops: In-house collision repair services offered at a new-car dealership.

deck lid: The deck lid covers the trunk opening.

dedicated bench: A frame straightening machine that uses jig-like structures called fixtures to identify damage and hold replacement parts in position.

deductible: The part of the repair cost a vehicle's owner is responsible for paying out-of-pocket.

desiccant: A substance that absorbs moisture.

detail cloth: A soft cloth rag that will not damage clean paint. The detail cloth is the preferred way to apply and wipe off hand glaze.

detailer: A person who carefully cleans repaired vehicles before delivery. Detailers may also apply decals and buff paint.

detailing: The systematic rejuvenation and protection of the various surfaces of a vehicle.

dicing: Tempered safety glass shatters into a predictable pattern called dicing. Dicing helps minimize injury to the vehicle's occupants.

die grinder: A tool that rotates a cutting bit at high speeds.

digital scale: Extremely precise scale capable of accuracy to one-hundredths of a gram. It is used to weigh tints.

dilution solvent: Product used to dissolve a thick paint down to a sprayable viscosity.

dimension sheet: Lists the dimensions of an undamaged vehicle.

dimensions: The linear measurements of width, height, and length.

direct repair agreement: An arrangement between a collision repair shop and an insurance company, where the customer brings their claim directly to that shop.

displaced metal: Undamaged metal held out of position by buckles or arrowheads.

dollies: Steel blocks, which have various crowned surfaces, used to repair damaged panels.

door: A panel with hinges that allow it to open and close, providing access to the passenger compartment.

door shell: Part of the door assembly. The door shell is the framework that supports all other door components.

door skin: The outer panel of a door.

door skin replacement tool: An air-powered tool that eliminates much of the hammer-and-dolly labor and minimizes the chances of damaging the new door skin.

double fold: More than one buckle located close together caused by longitudinal forces.

double grab hook: A device that ties two chains together or shortens a length of chain.

double stretch pull: Two pulls in opposite directions intended to straighten and then lengthen damaged metal. A double stretch pull can correct mash and sidesway.

downward pull: Frame straightening technique used to lower a damaged area. This type of pull is used to correct kickup and twist.

draw pin welder: Tool designed to weld pins to damaged sheet metal. These pins are used as anchoring points for pulling tools.

dressing welds: Involves grinding welds and removing scale to improve the appearance of a weld or to prepare the weld area for subsequent operations such as priming and painting.

drill bits: Tooling used to make holes in replacement panels and other parts.

drills: Tool used to bore holes.

drive away time: Cure time.

drive train: Produces power and conveys this power to the drive wheels.

drive-through spray booth: A spray booth with a door at each end. The vehicle enters through one end of the booth and exits through the other.

drop coat: Painting technique used to correct the orientation of aluminum flakes in a metallic paint.

dry spray: Occurs when not enough paint is applied to wet the surface. Dry spray is more noticeable in clearcoat than basecoat and is often mistaken for orange peel.

dry time: The amount of time required for the solvents to evaporate from a paint or primer.

dual-use undercoat: An undercoat that combines two functions. An example is primer-surfacer, which binds and fills.

dust mask: A flexible filter held over the nose and mouth by elastic or rubber straps. Intended to protect against dust generated while sanding.

dust-free time: The length of time required for paint to cure to a point where dirt will no longer stick.

duty cycle: The length of time, expressed as a percentage, that a welding machine can operate in a 10-minute period at a particular heat setting.

E

E-coat: An electrode position primer applied to a bare metal part at the factory.

edging: Pre-painting inaccessible areas of new replacement parts prior to installation. This is known as trimming or cutting in.

electric shears: Sheet metal cutting tool used to create patch panels or remove damaged areas.

electrode extension: The length of the wire protruding from the welding gun's contact tube. Also known as *stickout*.

electronic leak detector: Device used to check for escaping refrigerant. The detector will signal if escaping refrigerant is discovered.

electronic suspension system: System engineered to keep the vehicle level, even when carrying heavy loads.

encapsulated glass: A plastic frame molded around a piece of safety glass. The glass cannot be separated from the plastic frame.

endplay: A measurement of how far the axle can be pulled out and pushed in after installation. Excessive endplay must be adjusted.

engine cradle: Frame component that supports the engine, transaxle, front suspension, and rack-and-pinion assembly.

Environmental Protection Agency (EPA): An agency of the U.S. federal government created for the purpose of protecting human health and the environment by writing and enforcing regulations.

epoxy primer: An epoxy-based automotive primer that improves adhesion, is resistant to moisture, corrosion, and rust.

estimate: A body shop's statement of work to be done and the approximate cost of repair.

estimator: Person who inspects collision damaged vehicles and then prepares time, cost, materials, and labor estimates.

etcher: A liquid formulation used to remove microscopic rust formation and to prepare the bare steel to accept paint.

evacuation: Occurs when the air conditioning system is held under a vacuum for at least thirty minutes to pull water out.

evaporate: Phase change from liquid to gas.

evaporative emissions control system: Also known as an EVAP system, prevents the evaporation of fuel into the atmosphere by absorbing fuel vapors and routing them back to the engine to be burned.

evaporator: A system of tubes and fins located inside the passenger compartment. Air blowing over the evaporator is cooled. This cold air is directed into the passenger compartment, cooling the vehicle's interior.

exhaust fan: Pulls air in from outside the booth through intake filters, draws the air around the vehicle, and forces it out through exhaust filters.

exhaust system: Channels waste combustion gases from the engine to the rear of the vehicle.

F

fabricating: The process of making a part or component.

face bar: Another word for bumper.

face/head on: Colors can be viewed either straight-on or from an angle. The straight-on view is called face or head on.

factory pack color: Color mixed by the paint manufacturer.

fading: A gradual change in color often caused by exposure to the sun. Also refers to a custom painting technique where one color subtly changes into another color, popularly using adjacent colors on the color wheel.

false stretch: A bulge in a body panel that pops in when pressed and pops back out when released. False stretch is also known as *oil can*.

fan: The fan draws cool air through the radiator to maintain optimum engine temperature. Could also refer to the shape or pattern of atomized paint as it leaves the spray gun.

fan clutch: A device that allows the fan to slow or stop rotation at highway speeds.

fan knob: Also called a *pattern control knob*, the fan knob regulates the amount of air that flows through the air horns, and controls the shape and size of the spray pattern.

featheredging: A sanding technique which produces a gradual taper of the paint edges around a repair.

fenders: Outer body panels located between the front doors and the front bumper. They surround the front wheel openings and conceal front suspension components.

fiberglass resin: A component of fiberglass repair. Resin and hardener are mixed to make repairs.

filing: The use of a file at an angle to identify high and low spots in a panel.

finish dual-action sander: Also known as a *finish DA sander*, this tool spins a sanding disk in an oscillating pattern resulting in a smooth sanding action.

finishing: The final step in panel replacement. Finishing includes dressing welds, filling weld gaps, and applying rust proofing.

fire extinguisher: A device designed to remove at least one of these elements*:* extreme heat, oxygen, or fuel to put out a fire.

fish eye eliminator: Modifies paint chemistry to be similar to the chemistry of the contamination to a point where the paint is no longer repelled by the contaminant.

fish eyes: Paint defect caused by silicone contamination of the refinish surface.

fit-up: Panels to be lap welded must be tightly fitted, or fit-up, with no gaps.

fixed glass: Glass that does not move. All windshields, for example, are fixed glass.

flange joint: A stepped joint formed by a flange tool. The step allows a replacement panel to make a flush fit with an existing panel. The flange also stiffens the panel.

flash rust: When bare metal is exposed to air, it will almost instantly begin to rust as it reacts with the moisture and oxygen in the air. This invisible layer of rust is known as flash rust.

flash time: The number of minutes it takes for the solvents in freshly applied paint to evaporate, leaving the paint dry enough to touch.

flat rate manual: Also called a *collision estimating guide*, it lists flat rate labor allowances for replacing parts, moving and reinstalling parts, repairing panels, prepping for paint, and refinishing the vehicle.

flex agent: An additive that changes the paint by allowing it to remain pliable when deformed.

flexibility: A desirable characteristic of a durable paint. Paint must be flexible enough to move with the metal's expansion and contraction cycles. If paint is inflexible, it will crack.

flexible plastics: Classification of plastics that includes urethane (PUR) and thermoplastic olefin (TPO and TEO). Flexible plastics are chosen for exterior automotive applications such as bumpers. They are designed to deform under force and pop back into shape when the force is released.

float test: A quick test to determine whether or not a plastic contains olefin.

flood test: A way to check paint distribution within a spray pattern.

floor jack: A tool used to raise a vehicle. It can also be used to move vehicles with damage that prevents the front or rear wheels from turning.

floor pan: The base, or floor, of the passenger compartment. It is welded to the rocker panel and cowl.

floor pot system: Cups, cemented into the floor, used to anchor the vehicle and the towers during frame pulls.

floor rail system: Frame holding and pulling machine. In this system, the damaged vehicle is positioned within a rail grid that is imbedded in the shop floor.

flop: A paint condition in which the comparative lightness or darkness of a color changes as the viewing angle changes. Sometimes flop is called *pitch*.

flow out: The tendency of wet paint to level and smooth out immediately after spraying.

flow restrictor: A fitting that allows a certain amount of liquid to pass through a small opening into a larger area.

fluid control knob: Adjusts the amount of paint that is introduced into the airstream.

fluid tip: Business end of a paint spray gun. It contains a porthole that allows the paint to exit the spray gun.

flush: A term indicating that two or more adjacent panels are at the same surface level.

flux-cored arc welding: A wire-feed welding process that does not use traditional shielding gas. Instead, flux inside the hollow welding wire produces shielding gas when burned.

flux-cored wire: Hollow welding wire with a flux core. The heat of the welding process vaporizes the flux, and the flux vapor protects the weld from contamination.

flyback: Describes a dangerous condition where a chain being used in a frame pull breaks loose from its attachment point.

forward pull: A type of frame pull used to increase length of a damaged part parallel to the vehicle's centerline.

four-wheel alignment: Front-wheel-drive vehicles with adjustable rear wheels require a four-wheel alignment to check and set all four wheels to specifications.

frame bench: A holding and pulling machine onto which the vehicle cannot be driven. The bench is either assembled under the vehicle or the vehicle is raised and the bench is positioned underneath.

frame rack: A holding and pulling machine that the vehicle can be driven onto or pulled onto with a winch. Frame racks may tilt to allow easier loading.

frame wraps: Chains strong enough to tie down a full-frame vehicle.

franchise body shop: A franchise is a right granted to an individual or group to market a company's goods or services within a certain territory or location. An example of a franchise body shop is Maaco, with more than 500 locations throughout North America.

free electrons: In most atoms, the electrons in the outer shell are loosely held and can be freed to move from one atom to another. These are called free electrons.

friction: The friction (rubbing) of the brake pads or shoes against the rotor or drum causes the wheels to stop rotating.

frit: Black border around the perimeter of any urethane-set glass. It protects the urethane from sunlight damage.

front blend: A technique used when hiding a slight mismatch between the refinish paint and the vehicle paint. In a front blend, each coat covers slightly more area than the previous coat.

front clip: Consists of all the body parts ahead of the front seat.

front section: Another way of saying front clip, which is, all the body parts ahead of the front seat.

front-end alignment: Involves checking the suspension parts for damage or wear, measuring alignment angles, and setting all adjustable angles to specifications for the two front wheels.

full down-draft spray booth: A style of spray paint booth where air enters through filters on the roof, and is exhausted through the floor. Down-draft spray booths provide for the cleanest paint jobs.

full panel replacement: A repair technique where an entire damaged panel is removed from the vehicle at the factory seams and a replacement panel is welded or bonded in place.

full replacement: The replacement of an entire structural panel.

full-frame clamps: Clamps designed to do both anchoring and blocking.

full-frame vehicle: A vehicle, such as a pickup truck, where the frame is the main structure of the chassis; all other components fasten to it. Another term for this design is *body-on-frame* construction.

fusible link: A wire that is sensitive to excessive current. If excessive current is present, the wire melts, opening the circuit.

G

garnish molding: Windshield molding on the inside of a vehicle.

gauging: Making two-dimensional measurements of a vehicle is referred to as gauging. Gauging measures width related to the vehicle's centerline and height related to its datum.

general automotive repair technician: Makes mechanical repairs to damaged vehicles, such as replacing air conditioning, drive train, or suspension system components.

generator: The collision repair shop, generates, or creates waste. The shop (generator) is ultimately responsible for the waste even after a disposal company picks it up.

ghost flames: A custom painting design applying the ghosting painting technique to masked off flames on an auto body panel.

ghosting: Custom painting technique in which a design is masked off and the color applied is only slightly different from the background color. Only at the proper angle is the subtle color difference noticeable, and the design, visible.

glass cleaner: Product used to remove any residue that can interfere with adhesive bonding during repair.

glass label: Lists the manufacturer, plant code, type of glass, model number, date of manufacture, certification number, and glass code.

glass primer: Applied to glass to ensure a strong bond between the glass and the adhesive, and to block UV light.

glaze: Applied to the paint surface after buffing and polishing. It will fill and hide swirl marks, but the effects are temporary.

good housekeeping: Involves keeping the work area clean and well organized. This includes throwing away used masking paper, wiping cloths, cardboard packaging, and other flammable substances.

grab hook: One of three types of chain hooks used in collision repair. The grab hook attaches pulling chains to other chains.

gradations: Increments of measurement. A paint stick, for example, may have units of gradation (measurement) printed on the stick.

grinding disk: Round abrasive tool that can quickly remove paint, as well as metal.

ground: In an automobile, the vehicle's body serves as a conductor. It provides a pathway for electron flow known as the ground. The ground completes the circuit, allowing electrons to return to the battery.

guide coat: A very thin coat of primer or powder, of a contrasting color, used to detect high or low spots on a repair area.

gun orientation: The angle at which the welding gun is held at in relation to the work piece. The type of weld being made determines gun orientation.

H

hacksaw: Uses a saw blade specifically engineered to cut metal. A hacksaw consists of an adjustable metal frame and a detachable cutting blade.

halo effect: An undesirable paint defect caused by fanning the spray gun at the end of a stroke. Fanning will cause a slightly drier spray at the end of the stroke. This drier spray will cause the paint color to appear lighter at the edge.

hammers: A hand tool consisting of a handle with a head of metal or other heavy rigid material that is attached at a right angle. Used for striking or pounding.

hand punch: Hand operated tool designed to punch clean holes through sheet metal.

hardener: When added to paint, filler, or adhesives, hardener initiates a chemical reaction that causes cross-linking.

hat channel: The rear frame rail is sometimes called a hat channel. This is because the assembly, formed by the C-shaped rear rail and trunk floor, looks like a hat when turned upside down.

hazardous waste: Shop waste contaminated with paint particles or other dust created during collision repair. Hazardous waste must be disposed of properly.

header panel: Also known as a *headlight panel* because the headlights are mounted in it.

heat crayon: A tool used to determine the temperature of a heated panel. A heat crayon will melt at a specified temperature.

heated glass: Contains an electrical grid. This grid warms the glass, melting frost and removing moisture from the glass.

heating system: Heat from the coolant is used to warm the vehicle interior and defrost the windshield.

heeling: Any spray-fan orientation other than perpendicular to the panel is known as heeling. Heeling will cause more paint to be deposited on one end of the fan than on the other.

height: The distance of a point above datum.

hiding: A topcoat paint's ability to cover and not allow any color from below to show through. When the undercoat is no longer visible through the basecoat.

highlighting: Custom painting technique that involves applying a relatively light accent color immediately adjacent to a darker color. This style can create the illusion of three dimensions on a flat surface.

high-density foam: Dispensed as a two-part semi-liquid, high-density foam is pumped into cavities behind panels to make them more rigid.

high-metallic color: An aftermarket custom color containing larger-than-normal metallic flakes. Due to the large amount of gray added by the metallic, these colors tend to have less chroma when compared to nonmetallic colors.

high-strength steel: Steel featuring a different chemical composition than mild steel to make it harder and stronger. The carbon content of high-strength steel may be as high as 0.75%.

holdout: When topcoat paint is applied over any paint, including surfacer, the solvents in the topcoat may soak into the layer of paint below. Holdout is the ability of the surfacer to resist absorption of the topcoat.

hole saw: Tool commonly used to remove spot welds.

hood: The hood covers the engine compartment and is generally made of steel, aluminum, or rigid plastic. The hood is bolted to hinges that allow it to be opened and closed.

hood latch: The hood is held shut by the striker and the hood latch.

hook tool: Tool used to reach and remove the locking strip on rubber-set glass. The hook tool can also be used to break the seal between glass and a gasket.

hook-and-block tie-down: In this method, a frame hook is inserted into a hole in the frame or at a junction between a cross member and the frame rail. The chain on the hook is tied to the frame machine or to the floor.

hookups: Devices used to attach the pull to the damage. They must be stronger than the pull or the damage.

hose clamps: Hoses are attached to the engine and radiator with hose clamps.

hot-air welder: A small heat gun. Hot air from the gun's discharge tip heats the filler rod and the plastic part at the same time, fusing them together.

hue: Hue is the name of the color. Red, for example, is a hue.

hue shifting colors: A tri-coat paint that changes colors. When viewing the painted surface from different angles, the color changes.

hydraulic power set: Tool system that consists of a hydraulic pump, rams, extension tubes, and attachments. It's designed to push out damage.

hydraulic ram: This tool is used to apply the tons of pulling force required to straighten damaged areas.

hydrometer: Measures the specific gravity (or relative density) of liquids. In automotive applications it is used to measure the concentration of antifreeze.

hygroscopic: Readily absorbs water, such as water vapor in the air. Brake fluid is hygroscopic.

I

I-CAR: See *Inter-Industry Conference on Auto Collision Repair.*

idler arm: A major component of a parallelogram linkage. The idler arm is bolted to the vehicle's frame and moves as the center link pivots.

impact absorber: Foam-type impact absorbing material designed to protect the vehicle and its passengers. Impact absorber is found in bumpers.

impact bar: Part of a bumper. It is located behind the impact absorber and bolted to the lower frame rails.

impact wrench: A socket wrench power tool designed to deliver high torque output with minimal exertion by the user, by storing energy in a rotating mass, then delivering it suddenly to the output shaft.

included angle: The sum of the SAI (steering axis inclination) and the camber angle.

incomplete sentence questions: Also known as a fill-in-the-blank question, this type of question requires a chosen answer that best fits in the blank located within the question.

independent body shop: A stand-alone operation that is generally owned by one or two individuals.

induction period: The time after mixing when components in the paint are still interacting. An epoxy primer cannot be sprayed until the induction period has ended.

infrared dryer: When pointed at a panel, an infrared dryer raises the temperature of the paint in that one spot. It also cures by heating the surrounding air and raising the temperature of the entire vehicle. Infrared drying can cure paint in 10 minutes.

infrared lamps: Use heat to accelerate curing. The infrared energy excites molecules in the paint, producing heat, which shortens cure time.

infrared thermometer: A tool used to determine the temperature of a heated panel or to check the surface temperature of curing paint.

insulator: Prevents electricity from flowing anywhere but through the conductor.

insurance adjuster: A person who engages in the business of making an investigation for the purpose of obtaining information in the disposal of any claim in connection with a policy of insurance.

Inter-Industry Conference on Auto Collision Repair (I-CAR): An international nonprofit organization that trains professionals based on technical programs developed by the organization to reach all branches of the collision industry.

interior lights: Lights controlled by a switch located in the door opening. The action of the door shutting against this switch turns off the lights by opening the switch.

internal flow out: Wet paint will continue to level and smooth out until it dries.

internal rust: Unlike surface rust, internal rust begins on the inside of a panel and works its way out.

ISO code: A system for the identification of plastic parts. Many types of plastic have an ISO code number molded into the part.

isolators: A shock absorber-like device bolted between the impact bar and the frame rails.

J

jack stands: Used to support a vehicle after it has been raised with a jack. Jack stands are adjustable, allowing the vehicle to be secured at the proper height.

jigs: When a unibody vehicle is assembled at the factory, the structural parts, such as unirails and pillars, are affixed to fixtures, called jigs, for proper positioning during welding.

job shadow: In this type of arrangement, the student spends time observing what goes on in a business, such as a body shop.

jobber: Another word for supplier. Body shops often obtain paint from a jobber.

joining: Describes the permanent attachment of a replacement part to the vehicle.

joint: The area where the vehicle and the replacement part meet.

judgment labor allowance: An estimator examines the damage and calculates how many hours of labor are required to repair the damage. The time required to repair the damage is called a judgment labor allowance. Repair labor is also called judgment labor.

K

kinking: A metal shrinking technique that does not use heat. Kinking involves the use of a shrinking hammer (serrated-faced hammer) or a sharp pick hammer to reduce the surface area by gathering the metal together.

L

laminated glass: Safety glass made with plates of plastic or resin between two sheets of glass to resist shattering.

laminated steel: Comprised of two layers of steel bonded together with a solid layer of adhesive. The advantage of laminated steel over conventional single-layer steel is less noise and vibration.

lap joint: A welding term. It describes the bonding of one panel that is positioned on top of another. The edge of the top panel is welded to the bottom panel.

lap shear strength: The amount of force required to break a welded joint.

laser measuring system: A frame straightening system that uses a beam of light to form a straight line from the laser emitter to the target.

legend: Lists the type, shape, and size of various measuring points. It helps the technician locate the various measuring points on a vehicle.

length: The distance between two points measured parallel to the centerline.

let-down panel: A paper test card used by a painter to determine how many coats of midcoat are needed to match the existing paint.

level: Level in collision repair does not use the ground as a reference. The only reference is the vehicle itself. For example, for a bumper to be level, the ends of the bumper must be an equal distance from the hood or some other reference point on the body of the vehicle.

leveling: Leveling is the raising of low areas and the lowering the high areas. The dolly pushes up on the low areas as the hammer taps on the high areas.

leveling solvent: Reducer component that allows the paint film to stay wet long enough for leveling to take place.

lever: A rigid bar that pivots at one point and is used to move an object at a second point by a force applied at a third point.

liability claim: When the insured vehicle owner damages another vehicle. This is a liability claim. The insurance company will pay to repair the damage caused by the insured.

liability insurance: Insurance coverage to protect against claims alleging that one's negligence or inappropriate action resulted in bodily injury or property damage.

lift: A device used to raise up vehicles in the repair shop to allow for access to difficult to reach components.

lifting: An undesirable paint defect caused by a chemical reaction between an existing lacquer or thermoplastic paint layer and the solvent in the refinish paint. Lifting looks like shriveled paint.

lift reaction: During a pull, as the panel lengthens, the buckle unfolds or straightens. A pulling operation relies on the lift reaction to restore panel dimension as the damage is pulled out.

liquid mask: Applied with a spray gun, liquid mask dries to a film on the surface of the vehicle, and will protect the wheel wells, frame, roof and wheels from paint overspray.

locking strip tool: Opens the gasket to allow the locking strip to be installed.

loss: Damage to a vehicle is called *loss* by an insurance company.

low spot: A condition that describes damaged sheet metal that is below level.

low-density foam: A two-part semi-liquid that is sprayed or pumped into a cavity. The foam expands and changes to a solid as it cures.

lower frame rail: Also called a *lower front unirail*, the lower frame rail provides mountings for the drive train components. The lower front frame rail begins at the rear of the front bumper and is welded to the inner structure of the engine compartment and under the passenger's compartment.

lubricant: Substance used to help slip glass inside a gasket.

M

MacPherson strut assembly: A self-contained suspension unit that consists of a shock absorber and a coil spring.

MacPherson strut front suspension: In this system, the strut assembly is bolted to the steering knuckle and the strut tower. The coil spring allows the wheel to move upward within a certain range without moving the vehicle's body upward.

magnesium: An alloy that is lighter than aluminum, but it is just as strong.

make up air: Fresh air drawn in from outside the spray paint booth.

mapping: A surface defect that shows the contour outline of a body filler repair or featheredging operation. Mapping is caused by improper featheredging.

marbleizing: A custom painting technique that involves placing clear plastic food wrap on a wet, second contrasting color of basecoat to create a paint pattern resembling the random veins of color found in marble stone.

mar resistance: A quality of paint that is so tough and durable that it is not easily scratched by abrasion.

masking equipment: Tools designed to quickly dispense masking materials, such as masking paper, masking tape, or masking plastic.

masking paper: Material used to protect the vehicle from overspray when priming or painting.

masking plastic: A thin sheet of plastic designed to cover and protect a vehicle from unwanted overspray or shop dust.

masking tape: Adhesive tape used to hold masking paper in place, as well as to block paint.

mass tone: The color of a tint if it were sprayed onto a test panel.

material safety data sheet (MSDS): Source of information about the chemicals used in the collision repair shop. It lists the hazards posed by the product and is provided by the product manufacturer.

measuring arm: Tool used to locate underbody and upper body measuring points.

measuring bridge: Tool used to make three-dimensional measurements on damaged vehicles.

mechanical adhesion: A form of bonding during which the adhesive material (body filler, paint) physically locks into crevices (grinding scratches) of the surface.

mechanical aptitude: Talent for understanding and using machines or tools.

media blasting: Involves the use of compressed air to power (blast) an abrasive material (media). The media can be sand, silicon carbide, aluminum oxide, plastic beads, powder, or even walnut shells.

melt: A melt is a thin application of clearcoat A well-executed melt will make the line between the old and new clear coats invisible.

melt through: A hole burned through the workpiece. Occurs when the heat from the weld melts away the base metal.

mesh: A screen-like material used as reinforcement when making plastic repairs.

metal files: Hand tool with rows or sharp, parallel teeth intended for the rapid removal of metal. Also good for smoothing and shaping metal.

metal finishing: The removal of lows and highs by picking and filing after the roughing process is complete.

metal inert gas welding: A welding process which joins metals by heating them with an electric arc. Also called *MIG welding*.

metamerism: A condition in which two colors look the same under one type of light but look different under another type of light.

metering valve: Limits hydraulic pressure to the front brakes until a predetermined front input pressure is reached.

MIG welding: See *metal inert gas welding.*

mild steel: Steel with a carbon content of approximately 0.25%. Full-frames may be made from mild steel. Body panels are also made from mild steel.

mist coat: After the last coat of color is applied, a mist coat will evenly spread and position the metallic flake. This technique will eliminate defects such as mottling or tiger stripes.

mixing cup: A clear plastic cup with mixing ratios printed on it. Sometimes disposable, these cups are designed for fast and accurate paint formulation and mixing.

mixing sticks: Used to measure paint and stir components. Universal mixing sticks are marked into equal units. Dedicated mixing sticks are marked into part ratios for a particular type of paint.

motor mounts: Connect the engine to the vehicle's frame or unibody. Motor mounts contain a rubber section or are filled with thick liquid to isolate engine vibration from the vehicle.

mottling: A common paint defect on horizontal surfaces. Mottling means the metallic flake in the paint is unevenly distributed. Mottled paint looks blotchy, with light and dark areas.

movable glass: Glass that can change position. An example is a rollup window.

multiple pull: The term means to make more than one pull at a time. Each pull contributes to the corrective force. Less individual force is required to accomplish a task when multiple pulls are made.

N

NATEF: See *National Automotive Technicians Education Foundation.*

NATEF task list: List of standards that a collision repair training program must teach in order to receive NATEF accreditation.

National Automotive Technicians Education Foundation (NATEF): An independent, nonprofit organization that evaluates technician training programs against standards developed by the automotive industry and recommends qualifying programs for accreditation.

National Institute for Automotive Service Excellence (ASE): This nonprofit group works to improve the quality of vehicle repair and service by testing and certifying automotive professionals.

near spec: One of the two components of pitch.

negative pressure movement: Air, drawn in from outside the booth through intake filters, is drawn past the vehicle and is forced out through exhaust filters.

negative questions: Type of question requiring a chosen answer that does not agree—the exception—to the given statement. This form of question contains the words *except, not, least likely,* or *most likely.*

nib sanding: The purpose of nib sanding is to remove dirt from the base coat, not to sand the surface smooth. Some painters dry nib sand the basecoat with 1000-grit sandpaper before the final coat of basecoat is applied.

non-appearance weld: This type of weld is made on the inside of a panel; it is hidden from view.

nonpowered test light: Consists of a probe connected to a 12V bulb and a ground wire. If electricity is flowing in the circuit, the bulb in the test light will illuminate.

nonproduction jobs: Involve tasks that support production jobs, such as writing estimates and obtaining parts. In a production job, the employee performs the actual repairs.

nonstructural part: A structural part increases the strength of the vehicle. A nonstructural part does not make a vehicle any stronger.

nozzle: Directs shielding gas flow around the welding wire.

O

obvious damage: Clearly visible damage such as torn metal, buckles, and kinks.

Occupational Safety and Health Administration (OSHA): OSHA's mission is to assure safe and healthful working conditions by setting and enforcing standards and by providing training, outreach, education, and assistance.

OEM parts: OEM means "original equipment manufacturer". When referring to automotive parts, OEM designates a replacement part made by the manufacturer of the original part.

office manager: Supervises the estimator and parts personnel. Responsible for accepting payment from the customer and for releasing the repaired vehicle.

one-dimensional measurements: Measurements taken between two points.

one-part question: Type of question requiring a chosen answer based on a single fact.

one-sided repair: A repair where only the outside of the panel is worked. This type of repair is performed when the damaged panel is boxed or if accessing the back side of the panel is difficult.

open circuit: A broken wire causes an open circuit, or simply, an open. If a wire is broken, electricity will not flow through the circuit.

orange peel: A term used to describe an uneven surface texture. Literally looks like the bumpy surface of an orange. The many small bumps distort light or any image reflected in the panel.

orbital sander: This tool spins a coarse abrasive disk at high speed. This tool will rapidly sand filler. Also known as a *mud hog*.

original equipment manufacturer (OEM): The term original equipment manufacturer refers to the company that originally manufactured a given product.

oscillating knife: Features a blade that moves from side to side rather than in and out.

overheat: A condition where the engine temperature is above the normal operating range.

overlap: Spray pattern that covers part of the previous stroke. When painting, each stroke should overlap the previous stroke by 50%.

overpulling: Damaged panel is moved slightly beyond the correct location to account for settle back.

overspray: Paint blown past the target.

oxidation: A process in which the paint film combines with oxygen to dry/cure the finish.

ozone layer: A blanket of ozone (O_3) molecules in the earth's atmosphere. These molecules block some of the ultraviolet (UV) light from the sun.

P

paint code: Tells the technician what color is on the car. The technician uses this formula to combine tints to create the desired color.

paint diluting elements: Most paint must be diluted before spraying. Paint diluting elements such as thinner or reducer, are combined with paint to create a sprayable mixture.

paint formula: The recipe for a color. The paint formula contains a list of tints and the weight of each that should be added when mixing a specific paint color.

paint mixing room: A space set aside exclusively for mixing paint. The tints, mixing bank, scale, and paint formulas are kept in this room.

paint part number: Numerical code number assigned to a color by a specific paint manufacturer. The paint code and the vehicle model year are used to find the paint part number.

paint shaker: A mechanical device that thoroughly mixes paint components by vigorous shaking.

paint strainers: Device used to filter the mixed paint as it is poured into the paint gun cup. Some strainers are reusable, others are disposable.

paint thickness gauge: A tool used to determine the thickness of paint on a vehicle.

painting platform: A low-rise aluminum scaffold designed to raise the painter high enough to access difficult-to-reach areas, such as the hood or roof of a vehicle.

paintless dent repair: Involves pushing out, or raising, a low area in a panel without damaging the paint. Special rods are inserted into a panel to access the underside of the dent. The tip of the rod is used to push against the dent.

panel flanger: Device used to create a flange on sheet metal. A flange is a recessed lip that makes it easy to align sheet metal for joining.

panel painting: The refinishing of an entire panel.

panel positioner: This device uses arms and chains to hold and orient the bumper cover in a way that duplicates its original position on the vehicle. Positioners are available for doors, fenders, and even pickup truck boxes.

parallel circuit: A circuit that has more than one path for the electricity to flow through.

parallelogram steering gear: A component of the suspension that takes the rotating action of the steering wheel, turns it 90°, and transfers it to the pitman sector shaft.

Pascal's law: This law states that the pressure in a closed liquid system is uniform.

passive seat belts: Seat belts that do not require buckling, but automatically move into place each time the engine is started.

passive shaping: A technique where a damaged plastic part is placed into a hot environment in an effort to reshape the part.

pattern control knob: This spray gun mechanism regulates the amount of air that flows through the air horns. It controls the shape and size of the spray pattern. Also called a *fan knob*.

pattern test: Will show if the spray gun is adjusted correctly or if it needs cleaning. This test is performed to fine tune a spray gun.

peeling: A paint condition caused by the loss of adhesion between the topcoat and primer.

pendulum effect: Centerline pin misalignment caused by a vehicle with out-of-level or twist damage.

penetration: The depth of base metal melting during the welding process. Insufficient penetration will result in a weak weld.

picking: A hammer technique that raises small lows and lowers small highs. Both sides of the panel must be accessible for picking.

picks: These tools are designed to be inserted inside a panel to raise low spots. A pry pick can have a sharp end or a blunt end.

pilot hole: A small hole drilled in a panel to aid in the alignment of a larger drill bit.

pinch weld clamps: Most unibody vehicles are held in position on the straightening bench by pinch weld clamps placed on the bottom of the rocker panels.

pinch weld primer: Self-etching primer or paint used in areas where urethane will be applied to the pinch weld. The pinch weld primer will help form a strong bond between the urethane and the metal of the pinch weld.

piston air compressors: Similar in design to an internal combustion engine, air is let in and out of the cylinders by valves. The power to turn the crankshaft and to make the pistons compress air is provided by an external, usually electric, motor.

pit full down-draft spray booth: A style of paint spraying booth that draws exhaust air underneath the vehicle and into a pit. One of two types of full down-draft spray booths.

pitch: Viewing the vehicle at an angle is called pitch. Pitch can be broken down into two views*:* near spec and side tone.

pitman arm: This suspension component converts the rotation of the sector shaft to a back-and-forth motion and transfers this motion to the rest of the steering linkage.

pitman sector shaft: Steering/suspension component that moves the pitman arm back and forth.

pivot-point tie-down: One of two types of tie-downs, a pivot-point tie-down is positioned at the damage to act as a fulcrum. Pivot-point tie-downs prevent movement so the frame will bend at the desired location.

plastic paddle: Tool used to break the seal between the glass and the gasket. Because the paddle is plastic, it will not scratch surfaces like the hook tool.

plastic welder: Tool used to melt various types of plastic filler rods and base material.

plastic welding: A way to repair thermoplastics. In plastic welding, both the filler rod and the base material are melted.

pliers: Tool designed to grip or cut various objects.

plug weld: A weld made through a hole in one piece of metal that is lapped over another solid piece or metal.

plug welds: A type of weld used to duplicate factory spot welds on structural parts.

polish: A mildly abrasive product used to remove paint defects and bring the shine back to a faded finish.

polishing: A less aggressive buffing process intended to remove swirl marks made by compounding. Polishing involves the use of a less aggressive pad and a relatively fine abrasive (polish).

polymer: A large molecule made up of many smaller molecular units called monomers.

polymerization: Another word for curing. During polymerization, components in the paint react with each other.

positive pressure movement: A condition where the paint spray booth intake fan forces slightly more air into the booth than the exhaust fan pulls out. The excess air pushes out through cracks in the cabin walls and gaps in the doors, preventing the entry of contaminates.

pot life: The amount of time it will take for the mixed paint to cure under standard conditions of 70°F (21°C) and 50% humidity.

powder coating system: A process that applies an electrically charged, dry powder to grounded bare-metal parts, then melts the powder into a thick, uniform coating that doesn't run or sag, and is tougher than conventional paint.

power antenna system: Consists of a telescoping antenna, motor, and cable. Whenever the radio is turned on, the antenna goes up.

power brakes: A device that boosts the force from the brake pedal to the master cylinder, multiplying the force applied by the driver to the pedal.

power caulking gun: A tool, powered by air or electricity, that produces a uniform bead of caulk.

power door lock system: A system that uses solenoids to lock or unlock a vehicle's doors.

power mirror system: A system that uses electric motors to adjust mirrors.

power post: Heavy duty tool used to pull out major body and frame damage.

power seat system: A system that uses switches and electric motors to move and position the seat.

power sunroof system: Consists of a motor, switch, gears, and tracks, as well as drain tubes. The motor draws the sunroof open or closed along its tracks.

prep station: An area in the shop where the vehicle is readied for painting.

pre-paint solvent: Product formulated to remove fingerprints and minor oil-based contamination prior to the application of paint.

pre-sanding solvent: A solution blended to remove contaminants. This type of solvent is considered aggressive and will dissolve heavy tar contamination.

pressure relief valves: These valves are set to release air from the compressor when an excessive air pressure level is reached.

pressure washer: A tool that uses a high-pressure stream of water to clean a vehicle before it enters the paint shop.

pressure-differential valve: A device that senses low brake fluid pressure.

pressurized: When an engine is running, the cooling system is pressurized. In other words, there is more pressure inside the system than outside the system.

prevailing area wage: The hourly rate paid for work of a similar character in the locality in which the work is performed.

price fixing: A conspiracy between body shops to sell their services at a fixed price. The intent of price fixing is to push the price of the service as high as possible. This practice is illegal.

primary hue: The primary hues (colors) are red, yellow, and blue. Primary hues used in automotive refinishing are red, yellow, green, and blue.

primer: Coating that creates a bond between the bare metal and subsequent paint layers.

proportioning valve: To prevent rear-wheel lockup during a sudden stop, a proportioning valve is used to limit the amount of pressure exerted on the rear brakes.

pry bar: A heavy iron lever with one end forged into a wedge. Pry bars are used for prying and aligning.

pry picks: These tools are designed to be inserted inside a panel to raise low spots. A pry pick can have a sharp end or a blunt end.

pull: The power behind the straightening process. A pull attempts to duplicate the collision damage done to the vehicle in reverse, at a controlled rate.

pull hooks: Heavy-duty steel hooks designed to reach around an obstruction and push against the back side of the damage. Hooks have removable pull plates that are used to spread the force of the pull over a larger area.

pull plates: Steel plate with multiple attachment points that is bolted onto the damaged vehicle. The plate has enough holes in it to allow many different pulling combinations.

pull/push method: One of two methods of paintless dent repair. It requires pulling and pushing the tip of the rod across the dent while exerting delicate pressure.

pulling chain: An extra heavy-duty chain used to pull out damage.

punch: Tool used with a hammer to drive pins out of their corresponding holes.

punctual: A term used to describe an individual who is consistently prompt and on time. This is a desired characteristic to employers and displays respect for the business, owners, managers, and co-workers.

push method: In the push method of paintless dent repair, the technician raises the dent with the tip of the rod by making a series of small, delicate reverse dents in the panel.

push-pull wire feeder: Also known as a *spool gun*, has a motor in the gun to pull the wire while the drive rollers inside the MIG welding machine push the wire.

Q

quantitative formula: A paint formulation that lists the weight of each tint required.

quarter glass: Glass installed in the quarter panel, behind the door. It is typically found on two-door vehicles.

quarter panels: These panels form the sides of the vehicle's body behind the side doors and surround the rear wheel openings. They can be made of steel or plastic.

R

race: The surface in a hub that contacts the bearing.

radiator: A series of finned tubes that function as a heat exchanger. As air passes over the fins, the engine's heat is absorbed and removed by airflow.

radiator cap: Seals the cooling system and allows pressure to build within the system (to about 14 to 16 psi) when the engine is at operating temperature.

radiator hoses: Create a pathway for coolant to flow between the engine and the radiator.

radiator support: Located at the very front of a vehicle, the radiator support on many unibody vehicles is welded in place and adds strength and rigidity.

raising: A process of bringing low areas of body damage level with surrounding, undamaged sheet metal.

rear body panel: Located between the quarter panels, this panel forms the rear portion of the vehicle below the deck lid.

rear clip top: A section of the vehicle that contains all body parts up to the rear of the front seats.

rear defroster/demister system: A conductor grid on the inside of the rear window glass warms the surrounding glass and removes condensation or ice.

rear frame rail: A channel consisting of inner and outer panels and possibly a reinforcement. Provides support for the rear portion of a unibody vehicle.

rear hatch: Similar to the deck lid, but also contains the rear glass.

rear pillar: The part between the roof and the quarter panel. On a four-door vehicle, the rear pillar may be called a *C pillar*. Sometimes called a *sail panel*.

rear section: Consists of all body parts from the rear doors to the rear end.

receiver/dryer: Air conditioning system component that acts as a reservoir for the refrigerant. It removes moisture from the refrigerant. Also known as an *accumulator*.

reciprocating knife: Powered by air or electricity, the blade of this knife moves in and out.

recycled parts: Parts obtained from salvage vehicles.

recycling air system: A system that recovers discharged air and sends it back to the air compressor. The recovered air, which has already been dried and filtered, is recompressed and used again.

reducer: Solvent is used to dissolve a thick paint down to a sprayable viscosity. Enamel paint is diluted with reducer.

reducing: Enamel paint is diluted with reducer, a process known as reducing.

reduction: The process of adding solvents to paint is called reduction.

refrigerant identifier: A machine that determines whether the refrigerant is R-12, R-134a, or an unknown refrigerant.

refrigerant lines: Metal tubes and rubber hoses that form airtight connections between air conditioning system components.

refrigerator dryer: A component of an air conditioning system that cools compressed air, allowing for more efficient moisture removal.

reinforced fender: A type of fender found on vehicles that do not have a welded front inner structure. The reinforced fender has an outer skin welded to an inner panel.

relay: A magnetic switch that uses a low-voltage signal from a remote location to control the on-and-off operation of a high-voltage circuit.

remanufactured parts: Damaged or worn parts that have been repaired to OEM specifications.

repetitive stress injury: The inflammation of muscles or tendons caused by performing the same action again and again. Swelling of the inflamed area may affect nerves, causing pain or numbness.

replaceable bulb: A bulb, which can be replaced when burned out.

resistance welding: A type of welding that uses the resistance of the workpiece to the flow of electrical current to produce enough heat to melt panels together.

respirator: A mask designed to protect the lungs from harmful vapors and mists.

retainer: A plastic clip that snaps around the edge of the glass to secure it in the run channel.

retarder: Additive used to increase paint drying time.

reveal moldings: Moldings around the outside of a windshield.

ride height: The distance between a specified point on the vehicle and the shop floor.

right-to-know laws: Laws which require employers to inform workers about hazardous chemicals in the workplace.

rigid plastics: Classification of plastics that includes sheet molded compound (SMC) and fiberglass reinforced plastic (FRP). Hoods, tailgates, doors, truck beds, and cowl vent panels are made from this type of plastic. The least flexible type of plastic. It will move little, if at all, before breaking.

rivet gun: A tool used to install blind rivets, Pop rivets®, or rivets. Blind rivets are non-threaded fasteners used to join metal together.

rock guard: A protective coating that looks like heavy orange peel, typically applied to rocker panels and other lower body parts. Rock guard can be sprayed and dries to a thick, chip-resistant coating.

rocker panel spray: A thick, clear, protective layer that is sprayed on the lower surfaces of vehicles.

rocker panel: Located under the door openings, and extending from the end of the front fender to the beginning of the quarter panel, the rocker panel is a key structural part of unibody vehicles.

rod welder: Tool used to raise a low spot very quickly. Instead of using consumable draw pins, the tool welds on a rod that attaches to a slide hammer.

roof: The panel that covers the passenger compartment. Roofs are generally made of steel, but a few vehicles feature a rigid plastic roof.

rosebud tip: An attachment for an acetylene torch that is used to heat steel. It is designed to spread out the heat of the flame.

rotary screw air compressors: Type of air compressor that uses two rotors to trap and compress air.

rotating-pull clamp: A versatile device that can be used to set up a pull from many different angles.

rough cutting: A method of cutting where excess material is left in place rather than cutting to exact dimensions.

rough DA sander: A tool that can be used as a grinder or as a DA sander. Can be switched to a rough-mode specifically designed for the fast removal of excess material.

rub through: The act of buffing too long in one location removes all the paint and exposes the undercoat. This is called rub through. It is a paint defect commonly found on edges, high crown ridges, and body lines.

run channels: Tracks, lined with felt or rubber, in which movable window glass is contained.

run: A paint defect caused by gravity interacting with too much paint applied to a surface.

S

safety chain: A chain that prevents flyback if the pulling chain breaks or the hookup fails.

safety glass: Automotive glass designed to minimize the chances of injury if it is broken during a collision. All automotive windows are made of safety glass.

safety glasses: Eyewear designed to protect the eyes from most particles and liquids. The lenses used in safety glasses are rated according to their impact resistance.

safety goggles: Similar to safety glasses but the fit is tighter around the eyes. Goggles provide superior eye protection against particles and liquids.

safing sensor: Device used to detect rapid deceleration. Part of the air bag deployment system.

sail panel: The quarter panel meets the roof at the sail panel.

salvaged part: A used part taken from a salvaged vehicle.

sand scratch swelling: An unsightly paint defect. Basecoat can absorb reducer and the solvent from wax-and-grease remover. Subsequent basecoats will soak into the sanded basecoat and cause the sand scratches to swell.

sanding blocks: Hard rubber or soft foam blocks with provisions for attaching sandpaper. Used to find and repair high and low spots, and to achieve a smooth surface for paint application.

sanding pad: Softer than a sanding block, a sanding pad is used to give sandpaper a firm, yet pliable base of support.

sanding paste: A mild abrasive cleaner used to scuff clearcoat before blending. The abrasive in the paste scours the paint; cleaning and gently abrading.

sanding pen: A tool designed to reach into small, difficult-to-access areas. Rubbing the tip, made of bundled strands of fiberglass, over the existing paint abrades the surface, allowing adhesion of the refinish paint.

sanding stick: A sanding stick has no give so it produces a flat, level surface when block sanding. A paint mixing stick is often used as a sanding stick.

sandpaper: Abrasive-coated paper or cloth used for preparing a vehicle's body for painting. Sandpaper is available in a wide variety of abrasive grits.

sandpaper stripping: The use of sandpaper, not chemicals, to remove paint from a vehicle.

sandwich clamp: Frame pulling clamp used to repair a damaged unirail.

Schrader valves: An air conditioning system service fitting that is a different size from the service fitting on the high-pressure side. This prevents a mix-up in connectors.

scrapers: Any of various tools or utensils intended for scraping.

screwdriver: A hand tool for turning a screw, consisting of a handle attached to a long, narrow shank, which tapers and flattens out to a tip designed to fit into the slot in a screw.

scuffing: Technique used to put ridges and valleys into a paint surface. However, unlike sanding, scuffing uses very fine sandpaper and does not require a sealer or surfacer to fill scratches.

sealed beam: One of two types of headlight. Sealed beam contains a filament and the entire headlight is replaced when burned out.

sealer: An adhesion promoter, helps achieve a uniform topcoat color, forms a barrier over sensitive substrates, and provides hold out.

seam sealer: A tube-applied product used to make a joint between panels moisture proof.

secondary hue: Colors found between the primary hues when looking at a color wheel. If one part of blue is added to one part of red, you get violet, a secondary hue. A secondary hue is sometimes called tone or shade.

sectioning: Removing and replacing the damaged portion of a structural panel.

self-etching primer: Etches and primes bare metal in one step. It is applied to any bare metal before the glass is installed.

self-powered test light: Often called a *continuity tester*, the self-powered test light determines if there is a continuous pathway for electricity between the tester's probes.

self-tightening clamp: When placed inside the open end of a unirail, this type of clamp expands and holds onto the unirail as the clamp is being pulled.

semi down-draft spray booth: Air travels in through the roof at one end of the booth and out the other end. This path causes air to move over and across the vehicle.

semi-butt joint: A type of welding joint used when the flange tool cannot reach inside a panel to make a step.

semirigid plastics: Classification of plastics that includes polypropylene (PP), polycarbonate (PC), acrylonitrile butadiene styrene (ABS), vinyl, GTX, and Pulse. These plastics are currently used to manufacture interiors, consoles, dashboards, door panels, radiator shrouds, and fans. Like flexible plastics, they are designed to deform under force and pop back into shape when the force is released.

sensitization: Inhalation of isocyanates leads to sensitization. This means that whenever the individual breathes even a small amount of isocyanate-laden air, an asthma-like, acute reaction will occur.

series circuit: An electrical circuit with only one possible pathway for electron flow.

series-parallel circuit: These circuits have some electrical devices connected in series and others connected in parallel.

service cart: Wheeled cart used to transport tools from the toolbox to the vehicle where they will be within reach for easy access.

service fittings: Connection point where refrigerant is added to or removed from the air conditioning system.

service information: Instructions for repairing or replacing damaged components, as well as information on refinishing.

setback: A condition where the center of the wheel on one side of the vehicle is not directly across from the center of the wheel on the other side of the vehicle.

setting blocks: Fixtures placed at the bottom of the windshield glass. They correctly position the glass for installation.

settle back: A condition where once pulling tension is released, the panel returns to a position that still indicates damage.

set-up sheets: Schematics that list the location of control points and measuring points.

shade: A glass lens on a welding helmet that filters out harmful infrared and ultraviolet light.

shading: A custom painting technique that involves applying a relatively dark color to accent a light color. The lighter color is applied first and the darker shading is sprayed around the lighter color.

shock absorbers: A component of the suspension system that controls spring oscillations (up-and-down movements).

shock force: Corrective force. A shock force is applied as a series of blows rather than a constant force.

short circuit: Occurs when electric current takes an unintended pathway. An example of a short circuit is when a bare wire from one circuit touches a bare wire from a different circuit.

short/long arm suspension: A type of automobile suspension that uses upper and lower control arms of unequal length.

shrink fence: A line of small kinks made with a sharp pick hammer. The shrink fence tightens floppy metal in the low-crown area, allowing the filler to be sanded level.

shrink: The undesirable tendency for primer or surfacer coats to recede. This causes cracking and other unwanted defects in the topcoat.

shrinkage: Deep sanding scratches can trap solvent increasing the likelihood of surfacer swelling followed by shrinkage as the solvent slowly evaporates during curing.

shrinking: The act of decreasing the surface area of metal during repair is called shrinking. There are two types of shrinking: cold and hot.

side clip: A term used to describe the side of a vehicle. Parts of the side clip include the upper and lower frame rails, front shock tower, A-pillar, rocker panel, center pillar, quarter panel, rear shock tower, and rear frame rail.

side down-draft spray booth: This type of paint spray booth draws air through filters on the roof and blows it out through filters in the sidewalls.

side pull: A type of frame pull used to increase width at a 90° angle from centerline. This type of pull corrects sidesway.

side section: Same as side clip. A side section can consist of the entire side of a vehicle.

side tone: Viewing at an angle with the sun behind you as you look down the side of the vehicle.

side-load spray booth: A type of paint booth where the vehicle is loaded into the booth through the side as compared to the front or back.

simulated chrome: A custom painting design that makes a flat panel resemble a three-dimensional chrome bumper.

simulated wood grain: A custom painting design that makes a flat panel resemble a cross section of a tree trunk, with highlighted and shaded growth rings and fine grain lines.

single tint system: In this type of system, the tint contains pigment and solvent.

single-rail portable system: A type of frame pulling machine where the ram pushes against a stationary mount and the swing arm. As the ram extends, the swing arm pivots, exerting a pulling force on the chain.

single-stage piston air compressor: A type of compressor that draws air into a cylinder and a piston compresses the air in one stroke.

skin fender: A fender stamped from one piece of shaped metal. Vehicles with a welded front inner structure, such as most unibody vehicles, have skin fenders.

skip welding: In this welding method, the first weld is made in the center of the panel or joint. The second weld is made starting 1 1/2" to the left of the first weld. The third weld is made 1 1/2" to the right of the first weld. Finally, the gaps are welded to form a continuous weld bead.

slag: The nonmetallic layer that forms on top of molten metal, such as a weld bead.

sleeve joint: A way of joining panels where a 2"-wide sleeve that is the same length as the joint is slipped under the two panels and welded.

slide hammer: A versatile tool that screws into or is attached to a dent. The tool pulls out the damage by use of a sliding, integral weight.

slings: Straps wrapped around damaged rails or pillars. Slings may be made out of steel cable or nylon.

slip hook: A hook tool used to attach a chain to a clamp or a chain loop.

snips: Hand tool for making short, quick cuts in metal.

solid rear suspension: A solid rear axle that connects both rear wheels. If one wheel moves up or down, the other rear wheel is affected.

solvent: Substance capable of dissolving or dispersing other substances.

solvent pop: Paint defect caused by trapped solvents escaping through a partially cured paint film.

solvent recycler: Device engineered to remove contaminants from used solvent.

solvent-borne paint: Type of paint that uses highly volatile chemicals, such as ether, to carry the paint components in suspension. Most of the refinish paint used in collision repair shops is solvent-borne paint.

spatter: The hardened remains of molten metal that is thrown about during the welding process.

specification: A published standard used to determine vehicle body damage.

spectrophotometer: An electronic device that determines the color of a vehicle by measuring reflected light intensity (energy).

splice replacement: A repair technique where the damaged portion of a panel is removed and only a portion of the full replacement panel is installed.

spoon: A steel tool used to spread out the force of a hammer blow.

spot weld cutters: Tooling used to drill out spot welds.

spot welds: A factory spot weld is made by clamping the panels together between two electrodes. An electric current passes from one electrode to the other, fusing the clamped metal between the electrodes together.

spray booth: An enclosed area in which vehicles are painted. It is designed to remove dangerous paint mist from the surrounding air and protect the wet paint from outside contamination.

spray technique: The operation of the spray gun is known as spray technique and requires the balancing of several variables such as speed and distance.

spray-in bed liner: A thick and durable urethane, polyurethane-, or epoxy-based polymer engineered to protect the paint inside the truck bed.

spreader: A flexible plastic applicator tool used to mix and spread body filler.

spring back: Tendency of a frame to return to its damaged state once pulling tension is released. This occurs when the steel's grain misalignment is not corrected by the pull.

spring hammering: Technique to restore the grain pattern in damaged metal. While the component is under tension, spring hammering on the component will cause the grains to vibrate and move toward their original, undamaged arrangement.

springs: The compressible link between a vehicle's suspension and its body or frame.

stabilizer bar: A spring steel bar connected to the two lower control arms for the purpose of minimizing body roll.

standard: An example to be followed. A benchmark used to determine if damage or misalignment is present. Linear measurements are compared to a standard.

steel: A hard, strong, durable, malleable alloy of iron and carbon, usually containing between 0.2 and 1.5 percent carbon. Widely used as a structural material.

steering axis inclination: The angle between an imaginary line through the upper and lower ball joints, or the lower ball joint and strut mount, and a true vertical line.

steering column: Surrounds and supports the steering shaft.

steering gear: Changes the rotating motion of the steering shaft to a back-and-forth movement of the steering linkage.

steering knuckle: The connection between the steering and suspension systems. In automotive suspensions, a steering knuckle is the part that contains the wheel hub or spindle.

steering linkage: Components that transfer the motion of the steering gear to the vehicle's wheels.

steering shaft assembly: Connects the steering wheel to the steering gear.

stenciling: Custom painting technique that involves applying a stencil to mask off a portion of a painted panel. When a second color is sprayed over the stencil, a design is formed. Stencils can be as simple as a cardboard cutout or as complex as a reusable plastic stencil, or even a computer generated appliqué.

stick out: Electrode extension, or stick out, is the length of the wire protruding from the welding gun's contact tube. It determines the distance between the contact tube and the panel.

stitch weld: A short, but continuous bead about 3/4" long. The short bead length prevents the buildup of excess heat.

stops: Hood stops are rubber spacers designed to keep the hood at the proper height.

stress relief: To properly repair a full-frame vehicle, the steel's grain structure must be returned to the original undamaged state. Stress relief is an operation that gives the steel grains the energy needed to rearrange themselves back into their original configuration.

stretch: An increase in the surface area of a metal panel. A condition where the steel grains have been thinned, flattened, and elongated. A stretched area is repaired by shrinking the surface area.

stretching: Increasing the surface area of metal is called stretching. Stretching can restore the original dimensions to the damaged panel.

striker: The hood is held shut by the striker and the hood latch.

stripping: The act of removing all paint from a surface, leaving the metal bare. Paint can be stripped by chemical stripping, media blasting, or sanding.

stripping disc: An abrasive disc used to remove old finish and expose bare metal.

stroke: One pass of the spray gun at a specific distance and speed.

structural adhesive: Glue used to bond panels.

structural components: Components that protect passengers during a collision and support the weight of the vehicle. The strength of a vehicle is dependent on the integrity of structural components.

structural part: A body component that increases the strength of the vehicle.

strut rods: Metal bars mounted between a vehicle's body and a control arm. They prevent back-and-forth movement of control arms that have a single frame mount.

strut tower: A rigid structure that supports the front suspension.

strut tower gauge: This tool projects the alignment of the strut towers to the underside of the vehicle so it can be compared with the centerline gauges.

subtle damage: Damage that is difficult to find or easily overlooked during damage inspection. Subtle damage consists of light bulges and bends, raised areas between spot welds, out-of-level dimples in convolutions, and cracked or split caulking.

subtractive tinting: Tinting involves changing the color of refinish paint by adding or subtracting tints. In subtractive tinting, a specific tint or tints in a paint formula are left out when the paint is mixed.

suction cup: A tool that can be used to affix a handle onto glass to make the installation or removal of glass easier.

supplied-air respirator: A device that supplies the technician with clean, safe air from outside the spray area.

surface rust: External rust. Rust on the surface of a vehicle that has not yet penetrated.

Surform tool: A grater designed to remove body filler before final sanding.

suspension system: Isolates the vehicle's body from vibrations caused by the up-and-down movement of the wheels.

swing arm pulls: A repair system where the pull chain is attached to a swing arm. As a ram extends the swing arm, the chain is tightened.

switch: A device used to turn on and turn off the flow of electricity. When a switch is off (open), the circuit is not complete and current cannot flow. When the switch is on (closed), the circuit is complete and current can flow.

symmetrical: Measuring points that are the same distance from the centerline, the same height from datum, and the same distance in length measurement.

T

tack coat: A dry, slightly rough coat of paint. The rough surface allows the wet coats that follow to adhere without running.

tack rag: A loosely woven fabric coated with sticky resin. When gently wiped over a surface before painting, a tack rag will pick up and hold on to dust and other small particles of debris.

tailgate: A hinged flap at the back of a truck that can be lowered or removed when loading or unloading the vehicle.

taillights: All taillights have three functions—illumination, stop signal, and backup lights.

tap and die set: Metal cutting tools used to create screw threads, which is also known as *threading.*

target bases: Devices used to hold reflective targets in place during laser measurement.

team: A small group of people working together for a common purpose. Teamwork often requires flexibility and willingness to try new ways to get things done.

Tech-Cor: An organization that researches collision repair methods to set standards and guidelines for the industry. The information available is vehicle model specific and thoroughly detailed. The procedures explained are shop tested.

temperature crayon: A temperature measuring tool. It melts when a specified temperature has been reached. Temperature crayons are available in various melting temperatures.

tempered safety glass: A single layer of glass and is used on all windows except the windshield. It is harder than laminated glass and can withstand greater impacts.

tension: The force used to straighten damaged frames and sheet metal components. A straightening machine, for example, is a piece of tension repair equipment capable of producing ten tons of force.

texturing paint: Repairs will leave a smooth area on textured plastic. To restore texture, a special texturing paint is used.

thermoplastic: Paints that dry by evaporation of solvents only.

thermoset: A paint that dries by solvent evaporation and by a reaction such as oxidation or polymerization.

thermostat: A device that regulates coolant flow and keeps engine operating temperature in the optimum range.

thinning: The process of diluting lacquer paint with thinner.

three-dimensional measurements: Most accurate determination of damage information. All three dimensions—length, height, and width—are part of the measurement.

thrust-angle alignment: The act of checking to verify that the rear wheels follow directly behind the front wheels, as well as checking front wheel alignment.

tie-down: A device that secures a vehicle or frame so it does not move during straightening procedures such as pulling.

tie-down clamps: Devices designed to prevent vehicle movement during a frame pull.

tie-down hook: A component used during pulling that, when used with chains and clamps, prevents movement in all directions.

tie rods: Suspension component that provides a connection between the ends of the center link and the steering arms.

TIG welding: See *tungsten inert gas welding.*

tiger stripes: Dark bands visible in a light metallic color.

time window: The number of hours that fresh paint will accept additional coats without requiring sanding to promote adhesion.

tint mixing bank: An organized collection of tints used to modify and adjust paint color.

tinting chart: A color matching tool that shows the mass tone, the tint mixed with white, and the tint mixed with aluminum. This chart will give the painter an idea of how a tint will affect color.

tinting: Changing the color of refinish paint by adding or subtracting tints.

tire pressure monitoring system: A system where sensors in the tires inform the driver of incorrect tire pressure.

toe: A measure of the tire's orientation in relation to vehicle's centerline.

tolerance: Maximum allowable deviation from a standard.

toolbox: A box or case in which tools are kept.

topcoat: What you see when looking at a vehicle. The topcoat provides color, and because of exposure to the elements, it must be extremely durable.

torque-to-yield bolts: Suspension fasteners designed for one-use only.

torque wrench: A tool for setting and adjusting the tightness of nuts and bolts to a desired value.

total toe: Adding the left and right toe readings together determines total toe.

tower pull: In a tower pull the collar and roller can be moved up and down the tower as necessary.

tracking: The ability of the vehicle's rear wheels to line up and track directly behind its front wheels.

traction control system: The TCS automatically detects excessive wheel spin, controls engine torque, and applies the brakes to regain traction.

trailing arm: In a solid rear suspension, the control arms are attached to the unibody and the rear axle assembly. In this arrangement, the control arm is called a trailing arm.

tram: A straight bar with a fixed pointer and a sliding pointer for one-dimensional measurements.

transfer efficiency: A measure of the amount of paint that coats a surface compared to the amount of paint that is actually sprayed.

travel direction: The direction in which the welding gun is moved when making the weld.

travel speed: The rate (speed) at which the welding gun moves.

tricoat: In a tricoat there are two layers of paint underneath the clearcoat. The middle layer can be a translucent pearl. The pearl coat allows the color of the base to reflect through for a dazzling effect.

triggering: Proper triggering involves releasing the trigger at the end of the stroke and pulling the trigger just before the stroke begins.

trim code: Found inside the driver's door or in the dash on front of the driver, the trim code will tell what level of trim is on the vehicle.

trimming: Most shops pre-paint inaccessible areas of new replacement parts prior to installation. This is known as trimming, edging, or cutting in.

trunk floor: The area between the wheel house panels and the rear frame rails.

tubing flare: To form leak proof joints, the ends of a brake line are flared with a tubing flare tool.

tungsten inert gas welding: Different from wire-feed welding in that the consumable filler material for TIG welding is a rod that is added to the weld by hand.

two-dimensional measurements: A method of using height and width dimensions to locate a measuring point.

two-part questions: Type of question that can be viewed as a combination of two true-or-false questions. ASE tests use Technician A and Technician B in two-part questions. Both Technicians make a statement, perform a task, or evaluate a situation. After reading each of these statements and/or actions decide if either sentence is true. Then choose the appropriate answer based upon the decisions regarding Technician A and B.

two-rail portable system: This pulling system sets up quickly and is useful for light structural damage on unibody vehicles.

two-sided repair: A repair where both sides of the panel are worked. Access to the back side of the panel is required in a two-sided repair.

two-tone finish: A vehicle painted in two colors or in two shades of the same color.

U

unemployment benefits: State and federal funds available to technicians who lost their jobs due to lack of work.

unibody vehicle: A vehicle constructed of sheet metal panels that are spot welded together to form the main body structure. These panels provide the structural support for the vehicle, eliminating the need for a separate frame.

universal bench: A body repair system that uses jig-like structures to identify damage and hold replacement parts in position.

universal joints: Driveline components that allow the drive shaft to rotate while the suspension moves up and down.

upholstery removal tools: Tools designed specifically to remove upholstery components such as worn or broken springs, webbing, and seat covers.

upper frame rail: Component that adds strength to the upper portion of the engine compartment. It is welded to the radiator support and to the cowl.

upset: A reduction in surface area. The metal's grains have been shortened, thickened, and bunched together.

upward pull: A type of frame pull used to raise a damaged area. An upward pull corrects sag.

urethane adhesive: May be a one-part or two-part adhesive product and cure either by reacting with the moisture in the air or through a chemical reaction.

used parts: Parts obtained from salvage vehicles.

utility knife: A knife with a small, sometimes retractable, blade.

UV cure paint: A finish that contains a photo initiator and is designed to cure when exposed to UV radiation. Available as undercoats and clearcoats.

UV light: Light energy in the invisible ultraviolet spectrum.

UV radiation curing: The use of special UV lamps to cure paint. UV-cure undercoats can cure in less than 5 minutes.

V

vacuum system: Consists of a central vacuum unit, hoses, and special air tools. The tools feature internal ports designed to convey dust through the pad and into a canister.

value: The lightness or darkness of a color. Value is a measure of light intensity.

van side: A large steel panel that may or may not have window openings. The van side is spot welded to the roof, rocker panel, and front and rear reinforcement pillars.

vector pull: A type of frame pull where the pulling chain is stretched from the hookup to a chain anchor.

vehicle identification number (VIN): Found inside the driver's door or in the dash on front of the driver, or viewable through the windshield, the VIN includes information on the vehicle make, model, engine size, and production year, as well as the sequential production number.

vehicle safety rating: A measure of a vehicle's crashworthiness.

V-groove: A V-shaped indentation cut into the plastic part being repaired. A V-groove increases the contact area for the repair material (filler rod or adhesive).

viscosity: A measure of paint's liquid thickness.

viscosity cup: A tool used to measure the liquid thickness of paint.

volatile liquid: A liquid that evaporates readily when exposed to the air. Volatile liquids are the primary explosion hazard encountered by the collision repair technician.

volatile organic compounds: Hydrocarbon compounds that have low boiling points and therefore evaporate readily.

volume: The physical size, the amount of space occupied by a three-dimensional object. Paint can be reduced by volume. Volume can be measured in parts or percentages.

W

walking the panel: A painting method where the painter moves the spray gun down the length of the vehicle.

warp damage: A collection of high and low areas in a panel. Uncontrolled use of heat on a low-crown panel will cause warp damage.

wash primer: A special type of self-etching primer. Wash primer is thin and transparent. Also known as a *pre-coat primer.*

water pump: The heart of the cooling system. As the water pump pulley turns, blades inside the water pump circulate coolant.

water spots: A paint defect caused by water droplets landing on fresh paint. The spots look like a shallow crater in the paint or discoloration.

waterborne paint: Paint components are suspended in water. Although a waterborne paint does contain some volatile solvent, it is not nearly as much as is found in a solvent-borne paint.

wax-based rustproofing material: A dry, non-sticky invisible film engineered to protect metal body panels and welded joints from rust.

wedge clamp: An anchoring system that is fast and easy to install.

weld bonding: A combination of adhesive and squeeze-type resistance spot welding.

weld nugget: A spot weld is a small fused area, commonly referred to as a weld nugget.

weld puddle: The molten metal produced while the weld is being made. It can be made from melting the parent metal alone, the parent metal combined with filler metal, or mostly filler metal.

welding filler rod: A straight length of welding filler metal. Filler rod can be metal for welding steel, or plastic for welding plastic.

weld-on plate: A plate used to pull a body line or panel edge. One end of the plate is MIG welded to the damaged body line or panel edge. The other end of the plate has a ridge to accept a pulling clamp.

weld-through primer: A zinc-rich primer formulated to be applied over panels that are overlapped and then welded. This product protects areas that cannot be painted, but still need rust protection after the weld is complete.

wet coat: A painting technique that deposits more paint and stays liquid long enough to level out.

wheel alignment: A procedure that involves checking the suspension parts for damage or wear, measuring alignment angles, and setting all adjustable angles to specification.

wheel house: The part of the vehicle's body that surrounds the rear wheel.

wheel lockup: A condition that occurs when the brakes are applied so hard that the wheels stop turning before the vehicle stops moving. Locked wheels may cause a vehicle to skid out of control.

wheels: Circular rings that may be solid or spoked, capable of turning on an axle passing through its center.

widening: Occurs when, during a collision, the impact force traveling through the vehicle's frame may cause the frame rails to move away from each other.

width: The distance from a point to the vehicle's centerline. The centerline is an imaginary plane that runs down the center of a vehicle.

windshield knife: This knife's blade is inserted through the urethane adhesive and is then moved in a sawing motion.

windshield pillar: Also called the *A pillar,* the windshield pillar is a strong structural body part. The A pillar portion of the cowl is where the front door hinges are mounted.

windshield wire tool: A device which consists of two handles and a connecting wire which is fed between the windshield and the windshield pinch weld. The urethane is cut with a sawing action.

wiring harness: A collection of primary wires encased in a protective sleeve. The wiring harness provides an electrical pathway connecting electrical components throughout the vehicle.

Work Experience Reporting form: Upon registration with the ASE, an applicant will receive this form on which to list relevant work experience that, along with successfully completing the applicable ASE computer-based test, is necessary to become ASE certified. It is also available online at the ASE web site, www.ase.com.

work time: The number of minutes between adhesive mixing and curing.

wrenches: Tools used for gripping, twisting, or turning.

X

x-check: A pair of linear measurements that cut across one of the planes—centerline or datum.

Index

A

Abrasive disks, 622
Abrasive pads, 622–623
Abrasives, 618–623
    abrasive disks and pads, 622–623
    blasting material, 621
    cutoff wheel, 621
    grinding disk, 621–622
    sanding paste, 623
    sandpaper, 618–621
Accelerator, 609
Access window, 376
Accumulator, 523
Acid rain, 780
Active seat belts, 555
Active shaping, 264
Acute hazard, 32
Additional charges, 810
Additive tinting, 713
Additives, 606
Adhesion, 256, 672
Adhesion promoter, 261, 618, 747
Adhesion solvent, 607
Adhesives, 161, 260
Adjusters, 19
Aftermarket, 199
Aftermarket parts, 20, 199, 795
Aiming headlights, 482, 492–494
Aiming screws, 482
Air bag module, 559
Air bag systems, 557
Air bags, 557–569
    advanced systems, 560–562
    clean up, 566
    disabling system, 566
    replacing system parts, 566–569
    safety, 565
    safety procedures, 562–569
    systems, 557
Air cap, 580
Air change, 33
Air chisel, 154
Air compressor, 590
Air conditioning system, 521–528
    condenser service, 525–527
    damage, 524–525
    leakage, 528
    parts, 522–524
    recover, evacuation, recharging, 527–528
    service, 525
Air drying, 589
Air file, 152
Air hose, 596
Air intake system, 533
Air makeup unit, 584
Air pressure control knob, 651
Air punch/flanger, 153
Air ratchet, 127
Air regulator, 596
Air saw, 154
Alignment, 462–470
    adjustments, 468–470
    alignment values, 467–468
    angles, 464–465
    installing control heads, 466–467
    procedures, 465–466
Alignment bar, 144
Alloy, 58
Alternator, 481
Aluminum, 59
Aluminum foil, 627
Aluminum panel repair operations, 194–195
Aluminum preparation, surface, 695
Aluminum welding defects, 106
Ambient temperatures, 514
Anchoring, 382
Angle pull, 360
Anti-lock brake system (ABS), 498, 503–504
A-pillar
    pushed forward, 368
    pushed inward, 368–369
Appearance panel, 206
Appearance weld, 696
Application tools, 576–577
Apron, 63
Arcing, 658
Arrowheads, 75, 184–187
    folds, 186–187
Artistic masking, 754–755
ASE, 28, 820
    ASE certification, 819–828
    certification, 822–824
    tests, 824–826
    what it is, 820–821
ASE collision repair technician, 820

ASE master collision repair/refinishing technician, 820
ASE refinishing technician, 820
Assemblies, 798
Asymmetrical, 328
Atom, 476
Atomization, 578
Atomized, 33
Attachment, 171
Attitude, 834
Auto recycler, 27
Auto salvage yard, 27
Auto-darkening helmet, 90
Automotive paint store employee, 27
Automotive plastic, types, 258

B

Back blend, 729
Back taped, 680
Backer, 265
Baking, 584, 736
    paint application, 736–737
    removing masking materials, 737
Ball joints, 442
Banana knife, 289
Banding, 665
Bar hookup, 386
Base centerline gauges, 337
Basement full downdraft spray booth, 586
Basket-style pull, 313
Battery, 481
Battery and alternator service, 490–491
Bead, 96
Bed side, 63
Bed side replacement, 244–246
Belts, 534
Bench/rack system, 322
Bend, 71, 79
Bend-versus-kink rule, 79
Betterment, 795
Beveling, 266
Binder, 605
Binding, 266–267
Blasting equipment, 598
Bleeder valve, 507
Bleeding, 616
Blend, 697, 728–732
    creating, 728–730, 732
Blend coat, 662–663
Blended panel, 675
Blending, 611
Blending strategies
    adjacent panels, 733–736
    blend within repaired panel, 732
    paint application, 732–735
Blind picking, 181
Blind rivets, 125
Blistering, 741
Block sanded, 23
Block sanding, 574
Blocking, 306, 356–357, 382
Blowgun, 578
Blushing, 740
Body chisel, 145
Body filler, 158, 695
Body hammers, 138–141
Body line, 71
Body position, 657
Body repair, 21–22
Body repair hand tools, 138–151
    alignment bar, 144
    body chisel, 145
    body hammers, 138–141
    bull's-eye pick, 146
    cable-tensioning devices, 150
    dollies, 141–142
    door removal/alignment tools, 144–145
    filler tools, 146–147
    friction jack, 143–144
    hand punch, 146
    metal files, 145–146
    panel flanger, 146
    picks, 142
    shaping/sanding tools, 147–150
    slide hammer, 143
    spoons, 142
Body repair support positions, 27
Body shop employees, 25–27
Body shop estimates, 19
Body shop types, 24–25
Body style, 55
Body technician, 26
Bolted fixed glass, 294
Bolted nonstructural part replacement, 197–224
    part sources, 198–199
    replacement steps, 199–201
    replacing specific bolted parts, 201–222
Bolted part replacement
    deck lid, 218–219
    doors, 214–218
    fenders, 207–210
    header panel, 206–207
    hood, 210–214
    pickup bed, 221–222
    plastic bumpers, 204–206
    rear hatch, 219–220
    sliding door, 220–221
    specific parts, 201–222
    steel bumpers, 202–204
Bolted part replacement steps, 199–201
    analyze damage, 199
    final assembly, 201
    fit-up, 200–201
    plan repair, 200
    read estimate, 199
    remove damaged parts, 200
Bonding, 234, 269
Bone, 288
Bound electrons, 476
Bows, 62
Brake bleeding, 507–508
    ABS/TCS, 508
    manual, 507
    pressure, 507
Brake system parts, 499–505
    anti-lock brake system, 503–504
    brake fluid, 499–500
    brake lines and hoses, 500–501
    disc brakes, 502
    drum brakes, 501–502
    master cylinder, 500
    traction control and electronic stability systems, 504–505
    valves, 502–503
Brake system repair, 505–510
    brake bleeding, 507–508
    disconnecting brake line or hose, 506
    inspecting ABS components, 509–510
    moving brake line, 506
    replacing brake hose, 507
    replacing brake line, 506–507
    servicing disc brakes, 509
    servicing drum brakes, 508–509
    servicing worn components, 505
Brakes, 497–512
    operation, 498–499
    parts, 499–505
    repair, 505–510
Brazing, 111
Bridging, 616, 740
Buckle, 71
Buckles, repairing, 395–398
Buffer, 578
Buffing, 763–767
    materials, 628
Buffing window, 766
Bull's eye, 683, 750
Bull's-eye pick, 146, 181
Bumper assembly, 61
Bumper cover, 204
Bumpers
    plastic, 204–206
    steel, 202–204
Burns, 764
Bushings, 442
Butt joint, 93, 227

C

- Cab corner, 63
  - replacement, 246–247
- Cabinet blaster, 599–600
- Cable knife, 288
- Camber, 464
  - adjusting, 468–469
- Candy color, 753
- Captive blaster, 599
- Carbon monoxide, 47
- Cartridge-type respirator, 41
- Cast, 708
- Caster, adjusting, 468–469
- Caster angle, 464
- Catalyst, 159, 604
- Catalytic converter, 535
- Caulking gun, 290
- Center link, 440
  - replacing, 455
- Center pillar, 64
- Centerline, 328
- Centerline gauge, 336
- Chain basket hookup, 386
- Chain wrap hookup, 386
- Chain-and-block tie-down, 383
- Chalking, 675
- Chasing the dent, 180
- Chemical adhesion, 671
- Chemical paint removal, 623–628
  - buffing materials, 628
  - cleaners, 623–625
  - masking materials, 625–627
  - mixing/straining supplies, 627–628
  - paint stripper, 623, 677
- Chemical resistance, 610
- Chisels, 123
- Chroma, 702
- Chronic hazard, 32
- Circuits, 477
- Circuit breaker, 480
- Claim, 19
- Claim center, 19
- Claw hook, 305
- Clip, 420
- Clock spring, 484, 560
- Closed-coat, 618
- Coated glass, 282
- Coil spring impact sensor, 558
- Coil spring, replacing, 457
- Collapsed-hinge buckle, 73
- Collision damage
  - collision factors, 72–77
  - damage, 77–86
  - fundamentals, 69–88
  - vehicle design factors, 70–72
- Collision factors, 72–77
  - force, 72–75
  - impact angle, 76
  - inertia, 75
  - surface area of impact, 76–77
  - target, 76
  - vehicle height, 77
- Collision repair
  - body repair support positions, 26–27
  - body shop employees, 25–27
  - education opportunities, 27–28
  - industry jobs, 25–27
  - introduction to, 17–30
  - repair process, 18–25
- Color matching, 701–718
  - altering refinish color, 712–717
  - color description, 702
  - introduction, 702–703
  - light and color, 703–712
- Color sanding, 762
- Color wheel, 708
- Color-corrected lightbulbs, 705
- Colors, 706–707
  - mismatch, 707
- Combination crown, 72
- Combination damage, 404–405
- Combination pull, 360
- Combination technicians, 26
- Come-along, 150
- Comeback, 830
- Comparative laser, 344
- Comparison, 329
- Complete paint job, 665, 725
- Compound, 763
- Compounding, 763
- Comprehensive claim, 786
- Comprehensive insurance, 19
- Comprehensive tint system, 636
- Compressed air system, 128, 590–597
- Compressor, 522
- Computer-aided measuring systems, 345
- Computer-aided tram, 348–349
- Condensate, 595
- Condense, 521
- Condenser, 522
- Condenser service
  - checking refrigerant type, 525
  - connecting service fittings, 526
  - install O-rings, 527
  - plug lines, 526–527
  - replacement, 527
  - separating/connecting lines, 526
- Conductors, 476
- Cone, 331
- Constant velocity joint, 539
- Contact tube, 95
- Continuous weld, 92
- Control arm, 442
  - replacing, 458
- Control points, 342
- Coolant, 514
  - checking and mixing, 519
- Cooling, heating, and air conditioning systems, 513–530
  - air conditioning, 521–528
  - cooling, 514–521
  - heating, 521
  - hoses, 518–519
- Cooling system, 514–521
  - damage, 517–518
  - parts, 514–517
  - service, 518–521
- Core charge, 795
- Counter-point tie-down, 382
- Coverage chart, 726
- Cowl, 64
- Cowl vent panel, 62
- Cracking, 673
- Cradle-to-grave, 49
- Crash beam, 214
- Creeper, 131
- Cross camber, 464
- Cross caster, 465
- Cross-draft spray booth, 585
- Crosslinking, 608
- Crown, 71
- Cumulative formula, 637
- Curb weight, 452
- Cure, 260
- Curing, 604
- Custom painting, 752–758
  - airbrush, 754
  - artistic masking, 754
  - candy colors, 753
  - fading, 754–755
  - flames, 756–757
  - ghosting, 756
  - highlighting, 754
  - marbleizing, 756
  - masking, 755–756
  - shading, 754
  - simulated chrome, 757
  - simulated wood grain, 758
  - stenciling, 755
- Cut-off tool, 154
- Cutoff wheel, 621
- Cut-out knife, 288
- Cutting in, 698
- Cutting steel parts, 111–113
  - oxyacetylene cutting torch, 112–113
  - using plasma cutter, 111–113

D

- Damage
  - adhesive repair, 272
  - bend-versus-kink rule, 79
  - binding repair, 271–272
  - collision damage, 77–86
  - common types, 270–277

  - direct and indirect, 78
  - FRP break, 276–277
  - full-frame damage, 79–83
  - non-olefin repair, 271
  - olefin gouge (TPO, TEO), 273
  - olefin tear, 273–274
  - SMC break, 275–276
  - SMC or FRP scratch, 275
  - SMC splice, 276
  - thermoplastic break, 274–275
  - unibody damage, 83–86
- Damage diagram, 349
- Damage repair, fundamentals, 166
- Damming tape, 291
- Datum, 328
- Dealership body shops, 25
- Decals, 774–775
- Deck lid, 62, 218–219
- Dedicated bench, 341
- Deductible, 19
- Dent, 74, 182–184
- Desiccant, 523, 595
- Desiccant dryer, 595
- Detail cloth, 628
- Detailer, 26
- Detailing, 24, 761–783
  - adhesive-attached molding, 772–773
  - buffing, 763–767
  - clean up, 775–777
  - color sanding, 762–763
  - decals, 774–775
  - paint surface defects, 777–781
  - paintless dent repair, 767–771
  - pinstripe tape, 771–772
  - riveted-on molding clips, 773
- Diagnosing steering suspension, 449–454
- Diamond, 81
- Diamond damage, repairing, 402–403
- Dicing, 282
- Die grinder, 257
- Digital multimeter, 488
- Digital scale, 634
- Dilution solvent, 606–607
- Dimension sheet, 328
- Dimensions, 329
- Direct damage, 78
- Direct repair agreement, 19
- Disc brakes, 502
- Discharge air compressor, 591
- Displaced metal, 166
- Disposal fees, 810
- Dollies, 141–142
- Door removal and alignment tools, 144–145
- Door shell, 214
- Door skin, 214
- Door skin replacement, 247–251
- Door skin replacement tool, 155
- Doors, 62, 214–218
  - installing, 215–218
  - removing, 214–215
- Double fold, 168
- Double grab hook, 305
- Double stretch pull, 360
- Downward pull, 360
- Draw pin welder, 156
- Dressing welds, 236
- Drill bits, 127
- Drills, 127
- Drive away time, 292
- Drive axles, 539
- Drive belt and pulley service, 543–544
- Drive train, 55
- Drive train components, 536–541
  - all-wheel-drive, 540
  - four-wheel-drive, 540–541
  - front-wheel-drive, 539–540
  - rear-wheel-drive, 536–538
- Drive train orientation, 55
- Drive-through spray booth, 585
- Drop coat, 662, 739
- Drum brakes, 501–502
- Dry spray, 727, 741
- Drying equipment, 587–589
- Dual-use undercoat, 617
- Dust mask, 41
- Dust-free time, 611, 737
- Duty cycle, 95

E

- Ear protection, 40
- E-coat, 108, 617
- Edging, 696
- Educational opportunities, 27–28
  - ASE, 28
  - I-CAR, 28
- Elastic deformation, 70
- Elasticity, 70
- Electric shears, 155
- Electrical hazards, 36–37
- Electrical parts
  - basic, 478–480
  - fuses, fusible links, and circuit breakers, 480
  - motors, 480
  - switches and relays, 479
  - wire, 478
  - wire terminals and connectors, 478–479
- Electrical system service, 490–495
  - battery and alternator, 490–491
  - headlight aiming, 492–494
  - horn, 494
  - lighting, 491–492
  - power accessory, 494–495
  - windshield wiper/washer, 494
- Electrical systems, 475–496
  - basic electricity, 476–478
  - basic systems, 481–486
  - battery, charging system, and starting system, 481–482
  - electrical parts, 478–480
  - horn, 483–484
  - lighting, 482–483
  - power accessory, 484–486
  - system service, 490–495
  - tests and service operations, 486–490
  - windshield wiper/washer, 484
- Electrical tests and service operations, 486–487
- Electricity
  - basic, 476–478
  - circuit problems, 478
  - electrical components and circuits, 477–478
  - Ohm's law, 476
  - units, 476
- Electrode extension, 98
- Electronic leak detector, 528
- Electronic stability control system (ESC), 498
- Electronic suspension system, 446
- Employment strategies, 829–836
  - benefits, 831
  - goals, 830–831
  - job hunting, 832–833
  - succeeding in workplace, 833–835
- Encapsulated glass, 283, 298
- Endplay, 549
- Engine, 533–549
  - air intake system, 533
  - emissions control system, 534
  - engine pulleys, 534–535
  - exhaust system, 535–536
  - fuel system, 533–534
  - longitudinal, 547–549
  - motor mounts, 535
- Engine cradle, 64, 540, 546
  - adjusting, 470
- Environmental Protection Agency (EPA), 49–50
- Epoxy primer, 418
- Estimates, 786
  - computer-generated, 811–815
  - writing, 810–815
- Estimating, 785–818
  - additional charges, 810
  - calculating labor charges, 798–808
  - prices, 808–810
  - sourcing parts, 794–798
  - writing estimates, 810–815
- Estimator, 26, 786
  - identify damage, 787–790
  - insurance companies, 786–787
  - people skills, 786
  - quick checks, 790

  repair procedures, 792–793
  repair vs. replace, 793–794
  role of, 786–794
Etcher, 613
Evacuation, 527
Evaporate, 521
Evaporative emissions control system, 534
Evaporator, 523
Exhaust fan, 584
Exhaust system, 535
  service, 543
Explosion, 33–35

F

Fabricating, 269
Face bar, 202
Face/head on, 705
Factors, 800, 802
Factory pack color, 634
Fading, 609, 675, 754
False stretch, 175
Fan, 516
  removal, 520
Fan clutch, 516
Fan knob, 650
Featheredging, 680, 695
Fenders, 62, 207–210
  installing, 208–210
  removing, 208
Fiberglass resin, 261
Filing, 182
Finish dual-action sander, 577
Finishing, 187–194, 236, 269
  filling, 187–194
  metal, 187
Fire classifications, 34
Fire extinguishers, 33–34
Fire hazards, 32–33
Fish eye eliminator, 609
Fish eyes, 738
Fit up, 93, 233–234
Fixed glass, 283, 285–288
Flange joint, 227
Flash rust, 682
Flash time, 615, 724
Flat rate labor allowance, 798
Flat rate manual, 798
Flattening agent, 609
Flex agent, 609, 746
Flexibility, 610
Flexible plastics, 60, 746
Float test, 263, 747
Flood test, 655
Floor jack, 128
Floor pan, 64
Floor pot system, 318–320
Floor pots, 151
Floor rail system, 322
Flop, 708
Flow out, 607, 650
Flow restrictor, 522
Fluid control knob, 650
Fluid tip, 580
Flush, 201
Flux-cored arc welding, 105–106
Flux-cored wire, 95
Flyback, 304
Force, 72–75
Forward pull, 360
Four-wheel alignment, 463
Four-wheel-drive components, 549
Frame bench, 320
Frame damage
  collapsed cross member, 398–399
  combination damage, 404–405
  diamond damage, 402–403
  kickup, 401–402
  mash, 403–404
  repair buckles, 395–398
  rolled rail, 398
  sag, 401
  sidesway, 399–401
  specific types, 394–405
  twist, 402
  widening, 399
Frame machine types, 318–323
  bench/rack, 322
  floor pot system, 318–320
  floor rail system, 322–323
  frame bench, 320–321
  frame rack, 321–322
  portable system, 318
Frame rack, 321–322
Frame wraps, 306, 313
Franchise body shop, 25
Free electrons, 476
Friction, 499
Friction jack, 143
Frit, 286
Front blend, 728
Front clip, 420
Front section, 420
Front-end alignment, 462
Front-wheel-drive engine and transaxle assembly, 544–547
Fuel and emission control system service, 542–543
Fuel system, 533
Full downdraft spray booth, 586
Full frame repair allowance, 806–807
Full panel replacement, 226
Full replacement, 411
Full-frame clamps, 307, 383
Full-frame components
  full-frame replacement, 433
  full-frame sectioning, 432–433
  replacing, 432–433
Full-frame damage, 79–83
  front impact, 79–81
  rear impact, 82
  rollover, 83
  side impact, 81–82
Full-frame repair, 379–408
  basic operations, 380–394
  damage analysis, 381
  hookups, 386–390
  part removal, 381–382
  pulls, 390–393
  pushes, 393
  specific types, 394–405
  stress relief, 393–394
  tie-downs, 382–386
Full-frame vehicle, 54
Fusible link, 480

G

Garnish molding, 288
Gauging, 336
General automotive repair technician, 26
General-purpose hand tools, 119–126
  chisels and punches, 123–124
  hacksaw, 125
  hammers, 123
  pliers, 121
  pry bars, 122
  rivet gun, 125–126
  scrapers, 126
  screwdrivers, 122
  snips, 125
  tap and die set, 124–125
  upholstery removal tools, 126
  utility knives, 126
  wrenches, 119–121
Generator, 49
Ghost flames, 757
Ghosting, 756
Glass, 281–301
  introduction, 282
  movable and fixed, 283–288
  removal and installation tools, 288–292
  service, 292–298
  types, 282–283
Glass cleaner, 291
Glass label, 283
Glass primer, 291
Glass repair materials, 291–292
Glass service, 292–298
  bolted fixed, 294
  encapsulated, 298
  hinged, 293
  leak checks, 298
  rolling, 292–293

- rubber-set glass, locking strip, 295
- rubber-set glass, no locking strip, 294–295
- sliding, 293
- turning, 294
- urethane-set, 295–297

Glass service tools, 288–292
- hand tools, 288–290
- power tools, 290–291
- repair materials, 291–292

Glazing, 767
Grab hook, 305
Graduation, 643
Grains, 70
Grinder, 151
Grinding and cutting safety, 45–46
Grinding disk, 621
Ground, 477
Guide coat, 671
Gun orientation, 96

H

Hacksaw, 125
Half shafts, 539, 546–547
Halo effect, 728
Hammers, 123
Hand punch, 146
Hand tools, 119–126, 574–577
- application, 576–577
- body repair, 138–151
- general-purpose, 119–126
- removal, 576
- sanding, 574–576

Hardener, 261, 608
Hat channel, 430
Hazardous waste, 48–49, 587
Hazards, 32–38
- chemical and biological, 35–38
- electrical, 36
- explosion, 33–35
- fire, 32–33
- injury, 37–38
- noise, 36–37

Header panel, 61
- removing and installing, 206–207

Headlight aiming, 482, 492–494
Heat crayon, 364
Heat gun, 578
Heated glass, 283
Heating steel parts, 110
Heating system, 521
Heeling, 657
Height, 328
Hiding, 606, 611, 726
High spot, 167
High-density foam, 419
Highlighting, 754
High-metallic color, 753
High-strength steel, 58
- heating recommendations, 364

Hinged glass, 293
HLVP spray gun, 652–654
Hold out, 616
Hole saw, 230
Hood, 62, 210–214
- installing, 211–214
- removing, 210–211

Hood latch, 210
Hook-and-block tie-down, 382
Hook tool, 288
Hookups, 171, 309–313
- clamps, 309–310
- pull hooks, 311–312
- pull plates, 310–311
- slings, 312

Hose clamps, 515
Hoses
- checking, 518
- removing/replacing, 518–519

Hot-air welder, 259
Housekeeping, 32
Hub and wheel assemblies, 447–449
- tire pressure monitoring systems, 449
- tires, 448–449
- wheel hubs and bearings, 447
- wheels, 447–448

Hue, 702
Hue-shifting colors, 612
Hydraulic power set, 158
Hydraulic rams, 313–315
Hydrometer, 519
Hygroscopic, 500

I

I-CAR, 28, 835
Idler arm, 440
Impact absorber, 205
Impact angle, 76
Impact bar, 205
Impact wrench, 127
Included angle, 464
Incomplete sentence questions, 826
Independent body shop, 24
Indirect damage, 78
Induction period, 615
Inertia, 75
Inertia damage, 75
Inertia switch, 533
Infrared dryer, 684
Infrared lamps, 588
Infrared thermometer, 365, 600
Injury hazards, 37–38
Inner body assemblies, 63–65
Inner tie rod, replacing, 455
Insulator, 476
Insurance adjuster, 27
Insurance claims, 18–19
Inter-Industry Conference on Auto Collision Repair (I-CAR), 28, 835
Interior components, 554–562
- air bags, 557–562
- dashboard, 555
- seat belts, 555–557
- seats, 554
- steering column, 555
- windshield, 555

Interior lights, 483
Internal flow out, 650
Internal rust, 674
ISO code, 263
Isolators, 205

J

Jack stands, 129
J-clip, 204
Jigs, 341
J-nut, 204
Job shadowing, 830
Jobber, 634
Joining, 234–236
- bonding, 235
- weld bonding, 235–236

Joint, 227
- types, 93

Judgment labor allowance, 803–804
Jumper wire, 488

K

Kickup, 80
Kink, 79
Kinking, 180

L

Labor charges, 798–808
- additional labor, 807–808
- body labor allowance, 801
- flat rate labor allowance, 798–803
- judgment labor allowance, 803–804
- mechanical allowance, 801
- plastic repair allowance, 806–807
- refinish labor allowance, 801–803
- surface prep allowance, 804–806

Laminated glass, 60
Laminated safety glass, 282
Laminated steel, 59
Lap joint, 93, 227
Lap shear strength, 292
Laser measuring system, 344, 347
Lateral force, 74
Leaf spring, replacing, 458
Legend, 328
Length, 328
Let-down panel, 710–711, 731
Level, 200
Leveling, 175
Leveling solvent, 607
Lever, 380
Liability claim, 786
Liability insurance, 18
Lift reaction, 171
Lifting, 739
Lifts, 129
Light, 703–705
  how to view, 705
  sources, 704–705
Light and color, 703–712
  alternate formulas, 708
  colors, 706–707
  comparing two colors, 708
  comparison panel, 708–711
  light, 703–705
  plotting a color, 711–712
  refinish color, 712–717
  tricoats, 716–717
Lighting system, 482–483
Linear measurements, 328–331
Linkages, adjusting, 544
Liquid mask, 626, 681
Locking strip tool, 289
Long boards, 148
Longitudinal engine, 547–549
Longitudinal force, 73
Loss, 786
Low spot, 167
Low-density foam, 419
Lower frame rail, 63
Lubricant, 291

M

MacPherson strut assembly, 442
MacPherson strut, replacing, 456–457
MacPherson strut front suspension, 444
Magnesium, 60
Make up air, 35, 736
Mapping, 741
Mar resistance, 610
Marbleizing, 756
Mash, 80, 367, 403–404
Masking, 687–692
  adjacent panels, 692
  edges, 691–692
  equipment, 598
  for undercoats, 680–682
  moldings and stripes, 690
  panel openings, 688
  wheels and wheel openings, 690–691
  window moldings, 689
  windows, 689–690
Masking equipment, 598
Masking for undercoats, surface preparation, 680–682
Masking paper, 625
Masking plastic, 692
Masking tape, 625
Mass tone, 711
Material safety data sheet (MSDS), 50
Material types
  aluminum, 59
  glass, 60
  magnesium, 60
  plastic, 60
  steel, 58–59
  vehicle construction, 57–60
Measurements, 327–352
  damage diagram, 349
  linear measurements, 328–331
  one-dimensional, 331–336
  three-dimensional, 340–349
  two-dimensional, 336–340
Measuring arm, 346
Measuring bridge, 343
Measuring tools, 334–336
Mechanical adhesion, 188, 672
Mechanical aptitude, 26
Mechanical repairs, 22–23
Media blasting, 677
Melt, 698, 723
Melt through, 93
Mesh, 261
Metal conditioning, surface preparation, 682
Metal files, 145
Metal finishing, 187
Metal inert gas welding, 93
Metal properties, 70–71
Metamerism, 713
Metering valve, 503
MIG welder, 131
MIG welding, 43, 93–105
  aluminum, 104–105
  machine setup, 98–102
  problems, 99
  testing welds, 102–104
  variable, 96–98
  weld terminology, 96
Mild steel, 58
Mist coat, 662, 724
Mixing board, 146
Mixing cup, 627
Mixing sticks, 628
Mold release agent, 747
Motor mounts, 535, 544
Mottling, 662, 724, 738
Movable glass, 283–285
Multiple pull, 360, 391

N

NATEF, 28, 821
NATEF task list, 28
National Automotive Technicians Education Foundation (NATEF), 28, 821
National Institute for Automotive Service Excellence (ASE), 28, 820
Near-spec, 705
Negative pressure movement, 584
Negative questions, 826
Nib sanding, 727
Nonappearance weld, 696
Nonpowered test light, 487
Nonproduction jobs, 25–26
Nonstructural panel repair, 165–196
  accessing damage, 169–171
  aluminum panel repair operations, 194–195
  analyzing damage, 167–168
  fundamentals of damage repair, 166
  planning, 168–169
  reading the estimate, 167
  roughing out, 171–181
  steps, 166–194
Nonstructural panel replacement
  bed side, 244–246
  cab corner, 246–247
  door skin, 247–251
  patch panel, 251–252
  quarter panel, 237–240
  rear body, 244
  roof, 240–243
  van side, 247
Nonstructural panels, replacing specific, 237–252
Non-structural part, 61
Nonstructural repair materials, 158–161
  adhesives, 161
  body fillers, 158–159
  sandpaper, 159–161
Nonstructural repair tools, equipment, and materials, 137–164
  body repair hand tools, 138–151
  nonstructural repair materials, 158–161
  panel repair power tools, 151–158
Nozzle, 95

O

Obvious damage, 354
Occupational Safety and Health Administration (OSHA), 50
OEM clearcoat, 697
OEM parts, 20, 198, 794
OEM standard, 707
Office manager, 26
Offspray, 579
Ohm's law, 476
Olefin gouge (TPO, TEO), 273
Olefin tear, 273–274
One-dimensional measurements, 331–336
    measuring tools, 334–336
One-part question, 826
One-sided repair, 181
Open circuit, 478
Open-coat, 618
Orange peel, 727, 740, 777–778
Orbital sander, 152
Original equipment manufacturer parts (OEM), 794
O-rings, install, 527
Oscillating knife, 291
OSHA, 50
Outer body assemblies, 61–63
Outer tie rod end, replacing, 454–455
Overall paint job, 725
Overall painting, 727–728
Overheat, 514
Overlap, 660, 801
Overpour, 638
Overpulling, 362, 395
Overspray, 579
Oxidation, 604
Oxyacetylene torch, 109–110
Ozone layer, 522

P

Paint
    characteristics, 650
    components, 605–609
    diluting elements, 606–609
    formula, 637
    mixing, 632–639
    reduction, 639–645
    removal, 677–680
    sources, 634
    types of, 604–605, 662
Paint application, 719–744
    applying, 723–732
    baking, 736–737
    basecoat/clearcoat, 726–731
    blending, 732–736
    contamination prevention, 720–723
    plan repair, 720
    troubleshooting, 737–742
Paint coats
    applications, 661–662
    blend coat, 662
    drop coat, 662
    full wet coat, 661–662
    medium wet coat, 661
    mist coat, 662
    tack coat, 662
Paint code, 632, 796
Paint jobber, 27
Paint mixing, 632–639
    alternate paint part numbers, 633–634
    color creation, 638–639
    equipment, 634–636
    formula, 637–638
    paint code, 632
    paint mixing room, 587
    paint part number, 632–634
    supplies, 636–637
Paint part number, 632
Paint reduction, 639–645
    hardener type, 640
    reducer type, 640
    stirring, 639–640
    viscosity, 640–641
    volume, 641–644
    weight, 644–645
Paint shaker, 600, 635
Paint strainers, 627
Paint surface defects, removing, 777–781
Paint thickness gauge, 673
Painter, 26
Painting
    custom, 752–758
    plastic types and characteristics, 746–747
    safety, 46–47
    specialty, 745–760
    types of plastic parts, 751–752
Painting platform, 598
Paintless dent repair, 767–771
    painted stripes, 769–771
Paintless dent repair technician, 27
Panel flanger, 146
Panel painting, 724
Panel positioner, 598
Panel refinishing, 662–665
    long panels, 662
Panel repair power tools, 151–158
    air chisel, 154
    air file, 152
    air punch/flanger, 153–154
    air saw, 154
    cut-off tool, 154
    door skin replacement tool, 155
    draw pin welder, 156–157
    electric shears, 155
    grinder, 151–152
    hydraulic power set, 158
    orbital sander, 152–153
    rod welder, 157
    spot weld cutters, 153
    weld-on plate, 157
Panel spotter, 109
Parallel circuit, 477
Parallelogram steering gear, 440
Parallelogram steering gearbox, replacing, 456
Part sources, 198–199, 794–798
    aftermarket, 199
    OEM, 198
    used, 198–199
    vehicle codes, 795–798
Parts, ordering, 19–20
Parts person, 26
Pascal's law, 499
Passive seat belts, 557
Passive shaping, 264
Patch panel replacement, 251–252
Pattern control knob, 650
Pattern test, 654–655
Peeling, 674
Pendulum effect, 340
Penetration, 96
Personal protective gear, 39–42
    ear, 40
    eye, 39–40
    respiratory, 40–42
    skin, 42
Phosphating, 614
Picking, 181
Picks, 142
Pickup bed, 221–222
Pigment, 606
Pillar damage, 368–371
Pilot hole, 128
Pinch weld clamps, 356
Pinch weld primer, 291
Piston air compressors, 590
Pit full downdraft spray booth, 586
Pitch, 705
Pitman arm, 440
Pitman sector shaft, 440
Pivot-point tie-down, 382
Plasma cutter, 111–112
Plastic body filler, 22
Plastic bumpers, 204–206
    installing, 205–206
    removing, 205
Plastic deformation, 71
Plastic paddle, 288
Plastic parts
    flexible, 746–747
    preparing and spraying, 747–749
    sanding, 748
Plastic repair, 255–280

  classifying plastics, 257
  introduction, 256
  steps, 262–277
  tools and materials, 257–262
  types of damage, 270–277
Plastic repair allowance, 806–807
Plastic repair steps
  align damaged parts, 264–265
  clean repair area, 263
  finishing, 269–270
  identify plastic, 263
  make repair, 265–269
  plan repair, 263–264
  read estimate, 262
  remove damaged part, 262
Plastic welder, 257
Plastic welding, 267
Plastic wheel, 622
Plasticity, 71
Plastics
  bare, non-rigid, 749
  new rigid, 751–752
  primed non-rigid, 749–750
  repaired rigid, 751
  repaired non-rigid, 750
  surface preparation, 749–751
Pliers, 121
Plug welds, 92, 100–101, 415
Polish, 763
Polishing, 763
Polymer, 256
Polymerization, 604
Portable system, 318
Positive pressure movement, 584
Pot life, 608
Powder coating, 605, 612
Powder coating system, 600
Power antenna system, 486
Power brakes, 500
Power caulking gun, 290
Power door lock system, 485
Power mirror system, 485
Power post, 150
Power seat system, 485
Power sunroof system, 485
Power tools, 127–128, 577–583
  air ratchet, 127
  blow gun, 578
  buffers, 578
  drills and drill bits, 127–128
  heat gun, 578
  impact wrench, 127
  removal tools, 578
  sanding tools, 577–578
  spray guns, 578–583
Power train, 531–552
  drive train components, 536–541
  engine components, 532–536
  service and repair, 541–549
Power train fluids, checking, 541–542
Power window system, 484
Prep station, 587
Pre-paint solvent, 624, 687
Pre-sanding solvent, 624, 677
Pressure blaster, 599
Pressure relief valves, 592
Pressure washer, 598
Pressure-differential valve, 503
Pressurized, 514
Prevailing area wage, 809
Price fixing, 809
Prices
  labor rate, 809–810
  material, 808–809
  parts, 808
Primary hue, 702
Primer, 614
Production jobs, 25–26
Production manager, 26
Proportioning valve, 502
Pry bars, 122
Pry picks, 142
Pull hooks, 311
Pull plates, 310
Pull/push method, 768
Pulleys, 534
Pulling chain, 304–305
Pulling equipment, 304–315
  chain hooks, 305–306
  hookups, 309–313
  hydraulic rams, 313–315
  pulling chain, 304–305
  tie-downs, 306–309
Pulls, 315–318
  swing arm pull, 317–318
  tower pull, 315
  types, 360–362
  vector pull, 316–317
Punches, 124
Punctuality, 833–834
Push method, 768
Push-pull wire feeder, 105

Q

Quantitative formula, 637
Quarter glass, 283
Quarter panel replacement, 237–240
Quarter panels, 62

R

Race, 447
Rack-and-pinion gearbox, replacing, 456
Rack-and-pinion steering system, 439
Radiator, 514
  draining and filling, 519–520
  removing and replacing, 520–521
Radiator cap, 514
Radiator fins, 519
Radiator hoses, 515
Radiator support, 63
Raising, 175
Rear body panel, 64
  replacement, 244
Rear clip top, 420
Rear defroster/demister system, 486
Rear frame rail, 64
Rear hatch, 62, 219–220
Rear pillar, 64
Rear section, 420
Rear section and roof, 420
Reassembly, 24
Rebuilders, 18
Receiver/drier, 523
Reciprocating knife, 290
Recycled parts, 794
Recycling air system, 597
Reducer, 607
Reducing, 606
Reduction, 35
Refinish color, 712–717
  metallic orientation, 712–713
  tinting, 713–716
Refinish materials, 603–630
  abrasives, 618–623
  chemical paint removal, 623–628
  paint components, 605–609
  specialty topcoats, 612–613
  topcoats, 609–612
  types of paint, 604–605
  undercoats, 613–618
Refinish technician, 26
Refinishing, 23–24
Refinishing equipment, 583–598
  additional, 598–600
  drying equipment, 587–589
  maintenance, 586–587
  paint mixing room, 587
  prep station, 587
  spray booths, 583–586
Refinishing tools and equipment, 573–602
  additional equipment, 598–600
  hand tools, 574–577
  power tools, 577–583
  refinishing equipment, 583–598
Refrigerant identifier, 525
Refrigerant lines, 523
Refrigerator dryer, 595
Reinforced fender, 207
Reinforcement, 265
Relay, 479
Remanufactured parts, 20, 795
Removal tools, 576
Repair procedures, 266–269

Repair process, 18–25
  body repairs, 21–22
  body shop types, 24–25
  detailing, 24
  insurance claims, 18–19
  mechanical repairs, 22–23
  ordering parts, 19–20
  reassembly, 24
  refinishing, 23–24
Repetitive stress injury, 37
Replaceable bulb, 482
Replacement part sources, 419–421
Resistance welding, 107–109
  panel spotter, 109
  squeeze-type resistance spot welding machines, 107–108
Respirator, 42
Respiratory protection, 40–42
Restraint systems, 553–571
  interior components, 554–562
  service, 562–569
  types, 554
Retainer, 292
Retarder, 609
Reveal moldings, 288
Ride height, 452
Right-to-know laws, 50
Rigid plastics, 60, 746
Rivet gun, 125
Rock guard, 617
Rocker panel, 62, 427–428
Rocker panel spray, 694
Rod welder, 157
Rolling glass, 292–293
Roof, 62
Roof down, 374–375
Roof replacement, 240–243
Rope, 627
Rosebud tip, 110
Rotary screw air compressors, 590
Rotating-pull clamp, 310
Rough cutting, 228–231
  removing spot welds, 229–231
Rough DA sander, 577
Roughing out, 22
Roughing out panel repair process, 171–181
  edge alignment, 178
  leveling, 175
  picking/filing, 181
  pulling, 171–173
  pushing, 173–174
  raising, 175–177
  shrinking, 178–181
  specific types of damage, 181–184
  stretching, 174–175
Rub through, 764
Rubber-set glass
  locking strip, 295
  no locking strip, 294–295
Run, 737
Run channels, 284
Rust, 697

S

Safe work practices, 42–48
  grinding and cutting, 45–46
  mechanical repair, 47–48
  painting, 46–47
  sanding, 46
  straightening equipment, 44–45
  welding and cutting, 43–44
Safety, 31–52
  collision repair shop hazards, 32–38
  environmental regulations, 49–50
  hazardous wastes, 48–49
  introduction, 32
  personal protective gear, 39–42
  safe work practices, 42–48
Safety chain, 304
Safety equipment chart, 39
Safety glass, 282
Safety glasses, 39
Safety goggles, 39
Safing sensor, 559
Sag, 80, 401
Sail panel, 62
Sales tax, 810
Salvaged part, 419
Sand scratch swelling, 741
Sanding
  safety, 46
  tools, 574–576
Sanding blocks, 148, 574
Sanding pad, 574
Sanding paste, 623
Sanding pen, 576
Sanding stick, 149, 575
Sandpaper, 159–161, 618–621
  stripping, 678
Sandwich clamp, 310
Schrader valves, 523
Scrapers, 126
Scraping, 679
Screwdrivers, 122
Scuffing, 679
Sealed beam, 482
Sealer, 616
Seam sealer, 418, 625, 692–694
Seat belts, 555–557
Secondary hue, 702
Sectioning, 411
Self-etching primer, 291, 615
Self-motivation, 834
Self-powered test light, 487
Self-tightening clamp, 310
Semi-butt joint, 227
Semi-downdraft spray booth, 586
Semi-rigid plastics, 60, 746
Sensitization, 35
Series circuit, 477
Series-parallel circuit, 477
Service cart, 131
Service fittings, 523
Service information, 132–134
Setback, 465
Setting blocks, 296
Settle back, 362
Set-up sheets, 342
Shade, 90
Shading, 754
Shaping and sanding tools, 147–150
Shock absorbers, 442
Shock force, 172
Shop equipment, 128–132
  compressed air system, 128
  creepers and shop seats, 131
  floor jack, 128–129
  jack stands, 129
  lifts, 129–130
  service cart, 131
  welding equipment, 131–132
Shop foreman, 26
Shop hazards. *See* hazards.
Shop owner, 26
Short circuit, 478
Short/long arm suspension, 444
  replacing coil spring, 457
Shrink, 616
Shrink fence, 180
Shrinkage, 696
Shrinking, 139, 178
Side clip, 420
Side downdraft spray booth, 586
Side pull, 360
Side section, 420
Side tone, 705
Side-load spray booth, 585
Sidesway, 81, 367
  repairing, 399
Simple rolled buckles, 73
Simulated chrome, 757
Single tint system, 636
Single-stage paint, 723–726
  complete paint job, 725
  panel painting, 724, 726–727
  spot painting, 723
  two-tone finishes, 725–726
Single-stage piston air compressor, 590
Siphon blaster, 599
Skin fender, 207
Skip welding, 102
Skip welds, 415
Slag, 106
Sleeve joint, 227
Slide hammer, 143
Sliding door, 220–221

Sliding glass, 293
Slings, 312
Slip hook, 305
Snips, 125
Solid rear axle, replacing coil spring, 457
Solid rear suspension, 445
Solvent, 606
Solvent pop, 739
Solvent recycler, 590
Solvent-borne paint, 605
Spatter, 96
Specialty shops, 25
Specification, 328
Spectrophotometer, 712
Splice replacement, 226
Splicing, 21
Spoon, 142
Spot weld, 92, 102, 229
Spot weld cutters, 153
Spray booth, 583, 665
Spray gun, 578
  adjustments, 651–654
  air pressure recommendations, 652
  cleaner, 589
  cleaning, 667–668
  handling, 656–661
  HVLP, 579, 652–654
  setup, 651–654
  types, 578–583
Spray technique, 649–670
  introduction, 650–655
  painting considerations, 665–666
  painting skills, 656
Spraying body panels, 662–665
Spray-on bed liner, 613
Spreader, 147
Spring back, 394
Spring hammering, 363
Springs, 441
Stabilizer bar, 443
Stabilizer bar and links, 459
Standard, 328
Steel, 58
Steel bumpers, 202–204
  installing, 203–204
  removing, 203
Steering and suspension, 437–474
  alignment, 462–470
  diagnosing, 449–454
  hub and wheel assemblies, 447–449
  steering system, 438–439
  steering system types, 439–441
  suspension systems, 441–446
  system repair, 454–459
  wheel and tire service, 460–462
Steering axis inclination, 464
Steering column, 459
Steering gear, 438
Steering knuckle, 458
Steering linkage, 438, 440
Steering shaft assembly, 438
Steering system, 438–439
Steering system types, 439–441
  parallelogram steering, 440
  power steering system, 440–441
  rack-and-pinion steering, 439–440
Stenciling, 755
Stick out, 98
Stitch weld, 92, 101–102, 415
Stops, 210
Straightened, 21
Straightening damage
  pulls, 359–362
  pushes, 362–363
  unibody repair, 359–363
Stress relief, 393
  heating, 394
Stretch, 166
Stretching, 139, 174
Striker, 210
Stripping, 677
Stripping disk, 679
Stripping pad, 622
Stroke, 656, 660
Structural adhesive, 235
Structural component replacement, 409–435
  full-frame components, 432–433
  part sources, 419–421
  replacement procedures, 410–419
  unibody components, 421–432
Structural components, 410
Structural panel replacement
  fit up, 414–415
  join, 415–418
  reassemble, 419
  replace foam, 418–419
  rustproof and paint, 418
Structural panel replacement
  procedures, 410–419
  disassemble, 410
  plan, 411–412
  pretreat, 413–414
  remove damaged panel, 412–413
  straighten, 410–411
Structural part, 61
Structural technician, 26
Structural unibody components
  A-pillar, 425–427
  apron, 423
  center pillar, 428–430
  clipping, 431–432
  lower front frame rail, 425
  radiator support, 421–422
  rear frame rail and trunk floor, 430–431
  replacing, 421–432
  rocker panel, 427–428
  shock tower, 423–424
  upper frame rail, 424
Strut rods, 443
Strut tower, 63
Strut tower gauge, 336, 340
Sublet labor, 810
Substrate, 604
Subtle damage, 354
Subtractive tinting, 713
Suction cup, 289
Supplied-air respirator, 41
Surface area of impact, 76
Surface cure, 640
Surface preparation, 671–700
  basic procedures, 673
  block sanding, 684–686
  blow off vehicle, 687, 692
  damaged surfaces, 695–698
  finish sand, 686–687
  introduction to, 672–673
  mask for topcoat, 687–692
  masking, 680–682
  metal conditioning, 682
  paint removal, 677–680
  pre-paint solvent, 687
  pre-sand cleaning, 676–677
  remove obstructions, 676
  standards, 672
  wash, 676
Surface rust, 674, 697
Surfacer, 615
Surform tool, 147
Suspension systems, 441–446
  components, 441–443
  electronic suspension systems, 445–446
  front suspension types, 443–445
  rear suspension types 445
Swing arm pulls, 317
Switch, 479
Switches and relays, 479
Symmetrical, 328

T

Tack, 692
Tack coat, 662, 724
Tack rag, 624, 692
Tailgate, 63
Taillights/marker lights, 482
Tap and die set, 124
Target, 76
Target bases, 348
Team, 835
Teamwork, 834
Tear down, 21
Tech-Cor, 835
Temperature crayon, 110
Tempered glass, 60
Tempered safety glass, 282

Tension, 44, 172
Test light, 487–488
Test panel, 709–710
Texturing paint, 270
Thermoplastic, 604
Thermoset paint, 604
Thermostat, 516
Thinning, 606
Three-dimensional measurements, 340–349
  measuring tools, 341–349
Thrust-angle alignment, 462
Tie rods, 440
Tie-down clamps, 308
Tie-down hook, 307
Tie-downs, 306–309, 356–357
TIG welding, 106–107
Tiger stripes, 724
Time window, 726
Tint mixing bank, 635
Tinting, 713–716
  additive, 713–715
  chart, 711
  subtractive, 715–716
Tire pressure monitoring system, 449
Tires, 448–449
Toe, 464
  adjusting, 469–470
Tolerance, 332
Tool storage, 118
Toolbox, 118
Tools and equipment
  general-purpose, 117–135
  hand tools, 119–126
  power tools, 127–128
  service information, 132–134
  shop equipment, 128–132
  storage, 118
Topcoats, 24, 604, 609–619
  basecoat/clearcoat, 611–612
  single-stage, 611–619
  specialty, 612–613
  tri-coat, 612
Torque to yield, 789
Torque wrenches, 121
Total loss, 18
Total toe, 464
Tower pull, 315
Tracking, 453
Traction control system (TCS), 498, 504
Trailing arm, 445
Tram, 334
Transfer efficiency, 35
Travel direction, 98
Travel speed, 96, 659
Tricoat, 716–717
  applying, 731–732
Triggering, 661
Trim code, 796
Trimming, 698
Trunk floor, 64
Tubing flare tool, 500
Tungsten inert gas welding, 106–107
Turn signal lamps, 482
Turning glass, 294
Twist, 81, 371
  repairing, 402
Two-dimensional measurements, 336–340
  measuring tools, 336–340
Two-part questions, 826
Two-sided repair, 182
Two-stage piston air compressor, 591
Two-tone finish, 725
Two-tone painting, 731

U

Ultrasound measuring system, 347
Undercoats, 23, 604, 613–618, 682–684
  adhesion promoter, 617
  apply, 682–684
  curing, 684
  definition, 604
  dual-use, 617
  etchers, 613–614
  masking, 680–682
  primers, 614–615, 683
  rock guard, 617
  sealer, 616–617, 684
  surfacer, 615–616, 683
Unemployment benefits, 831
Unibody damage, 83–86
  front impact, 84–85
  rear impact, 85–86
  rollover, 86
  side impact, 85
Unibody repair allowance, 806–807
Unibody straightening, 353–378
  A-pillar, 368–370
  basic straightening operations, 354–376
  center pillar in, 371–373
  front unirail kickup, 366–367
  front unirail sag, 366
  front unirail sidesway, 367
  hookups, 357–358
  identify damage, 354–355
  rear unirail damage, 375–376
  repair plan, 355–356
  rocker panel in, 373–374
  roof down, 374–375
  roof rail up, 370
  specific types, 365–376
  straightening damage, 359–363
  stress relief, 363–365
  tear down, 354
  tie-downs, 356–357
  twist, 371
  unirail flange bent, 365
  unirail mash, 367
Unibody vehicle, 54
Unibody/frame straightening equipment, 303–326
  frame machine types, 318–323
  pulling equipment, 304–315
  pulls, 315–318
Universal bench, 341
Universal joints, 537
Upholstery removal tools, 126
Upper frame rail, 63
Upset, 78, 166
Upward pull, 360
Urethane adhesive, 292
Urethane-set glass, 295–297
Urethane-set windshield, 286
Used parts, 20, 198–199, 794
Utility knife, 126
UV cure paint, 604
UV curing, 588–589
UV dryers, 588
UV light, 159
UV radiation, 684

V

Vacuum blaster, 599
Vacuum system, 590
Value, 702
Van side, 63
  replacement, 247
Vector pull, 316
Vehicle classifications, 54–57
  body styles, 55–57
  drive train orientation, 55
  vehicle construction, 54
Vehicle codes, part sources, 795–798
Vehicle construction, 53–68
  classifications, 54–57
  material types, 57–60
  parts, 60–65
  production, 65–66
  safety rating, 66–67
Vehicle design factors, 70–72
Vehicle height, 77
Vehicle identification number (VIN), 796
Vehicle production, 65–66
  construction, 65–66
Vehicle safety rating, 66–67
V-groove, 265–266
Viscosity, 640
Viscosity cup, 606
Volatile liquid, 33
Volatile organic compounds (VOCs), 33
Volume, 641
Volume reduction, paint, 641–644

W

Walking the panel, 662
Warp damage, 179
Wash primer, 615
Water pump, 515
Water spots, 741
Waterborne paint, 605
Wax-based rustproofing, 418
Wedge clamp, 309
Weld, 696–697
  types, 92
Weld nugget, 92
Weld puddle, 93
Welded and bonded nonstructural panel replacement, 225–254
  analyze damage, 226–227
  final cutting, 231
  finishing, 236–237
  fit up, 233–234
  joining, 234–236
  plan repair, 227
  preparing panels, 231–233
  read estimate, 226
  replacing specific panels, 237–252
  rough cutting, 228–231
  steps, 226–237
Welding
  filler rod, 259
  fundamentals, 92–93
  position, 92–93
Welding and cutting, 89–116
  brazing, 111
  cutting steel parts, 111–113
  flux-cored arc welding, 105–106
  fundamentals, 92–93
  heating steel parts, 110–111
  MIG welding, 93–105
  resistance welding, 107–109
  safety, 43–44
  tungsten inert gas welding, 106–107
  using oxyacetylene torch, 109–110
  welding safety, 90–91
Weld-on plate, 157
Weld-through primer, 93, 233
Wet coat, 650
Wheel alignment, 462
Wheel and tire service, 460–462
  balancing, 462
  removing and installing tire, 461
  sealed wheel bearings, 460–461
  tapered wheel bearings, 460
Wheel assembly damage, diagnosing, 449–454
Wheel house, 64
Wheel lockup, 503
Wheels, 447–448
Widening, 399
Width, 328
Windshield knife, 289
Windshield pillar, 64
Windshield wire tool, 289
Wire, 478
  terminals and connectors, 478–479
Wiring diagrams, 489
Wiring harness, 478, 560
Wiring repairs, 489–490
Work Experience Reporting Form, 822
Work hardening, 71
Work time, 260
Working time, 250
Wrecker operator, 26
Wrenches, 119

X

X-check, 328

Y

Yield point, 73

Auto Collision Repair and Refinishing

Auto Collision Repair and Refinishing details the latest collision repair and refinishing techniques. This comprehensive textbook presents both the theoretical and practical aspects of collision repair and refinishing in an easy-to-understand manner. It includes information on structural repair, nonstructural repair, mechanical and electrical repair, refinishing, and estimating.

Auto Collision Repair and Refinishing is an indispensable resource for those preparing for a career in collision repair and refinishing, as well as experienced technicians preparing for the ASE collision repair and refinishing certification tests.

Features

- Organized around the NATEF Collision Repair and Refinish Task List.
- Detailed chapters on mechanical systems allow you to recognize and repair common types of mechanical damage encountered in the collision repair shop.
- The extensive estimating chapter provides unsurpassed instruction on this vital task.
- Full-color photographs and illustrations are used throughout to enhance understanding.
- Chapter reviews contain both conventional questions and ASE-type questions.

Other Automotive Titles from Goodheart-Willcox

- **Auto Engine Repair.** Covers the construction, operation, diagnosis, and repair of engines found in today's cars and light trucks.
- **Automatic Transmissions and Transaxles.** Covers the design, construction, operation, diagnosis, service, and repair of automatic transmissions and transaxles.
- **Manual Drive Trains and Axles.** Contains the latest information on the operation, diagnosis, service, and repair of manual transmissions and transaxles, as well as clutches, drive axles, drive shafts, half shafts, CV joints, universal joints, and four-wheel drive/all-wheel drive components.
- **Auto Suspension and Steering.** Teaches the skills needed to successfully diagnose, service, and repair all types of automotive suspension and steering systems.
- **Auto Brakes.** Details the theory, operation, diagnosis, and service of modern brake systems.
- **Auto Electricity and Electronics.** Covers the operation, diagnosis, and service of electrical, electronic, and computer-controlled systems found in today's cars and light trucks.
- **Auto Heating and Air Conditioning.** Details the operation, diagnosis, and service of automotive heating, ventilation, and air conditioning systems.
- **Auto Engine Performance and Driveability.** Teaches the skills necessary to diagnose and repair engine performance and driveability problems.

ISBN 978-1-61960-387-5
90000
9 781619 603875